The Remarkable Odyssey of Jane Luu

ASTRONOMY®

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Wormholes and Space-Time Paradoxes

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Get Ready for Comet Hale-Bopp

Comet De Vico
Prelude to the Big One?

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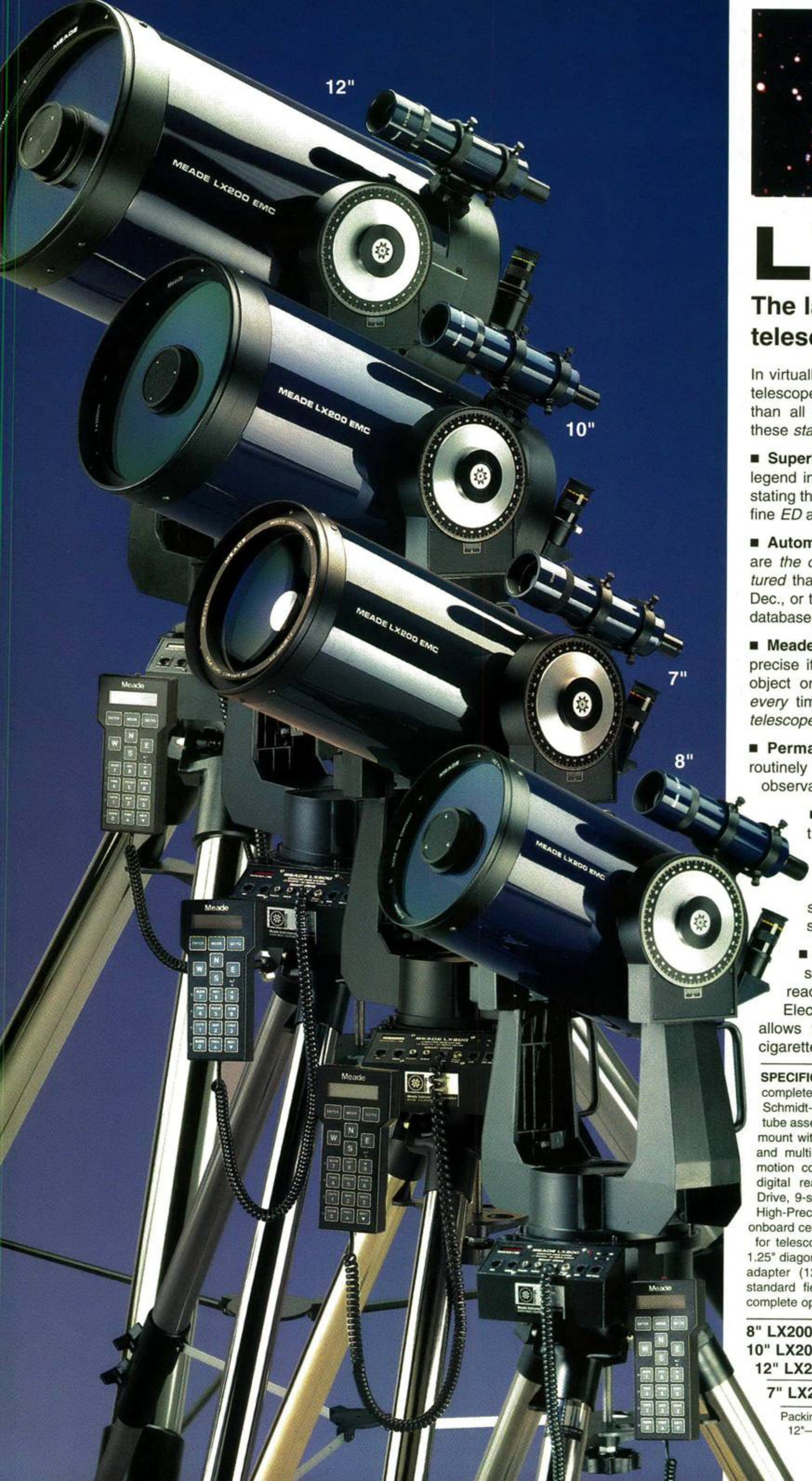
Secrets of Multi-Exposure Skyshooting

How To Zap Dew and Frost



LX200

The largest-selling serious telescopes in the world.

In virtually every country in the world where serious telescopes are sold, more Meade LX200's are sold than all competing models ***combined***. Consider these *standard-equipment* specifications:

- **Superb Optics:** LX200 imaging capabilities are a legend in the industry; we regularly receive reports stating that optical performance approaches that of a fine *ED* apochromatic lens.
- **Automatic GO TO Capability:** Meade LX200's are *the only commercial telescopes ever manufactured* that automatically GO TO any input R.A. and Dec., or to any of over 64,350 objects in the onboard database, *to a precision of one arc-minute or better.*
- **Meade LX200 High-Precision Pointing™** is so precise it permits the positioning of *every* selected object on *every* commercially-available CCD chip *every* time, automatically — *a feat that no other telescope priced under $40,000 can accomplish.*
- **Permanently-Programmable Smart Drive™** routinely achieves 5 arc. sec. periodic error, an observatory standard.
- **9-Speed Dual-Axis Electronics:** Electronics that cover every possible contingency of telescope positioning—from 2x photo-guide, to 32x image centering, to 8°/sec. slewing across the sky, as well as 6 other dual-axis drive speeds in between.
- **Field Operation:** No other telescopes of such incredible capabilities transport so readily for field operation. The optional #1812 Electronic DC Adapter (a compact 4 oz. unit) allows for field powering directly from an auto cigarette lighter plug.

SPECIFICATIONS: 7", 8", 10", and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm gears, and multi-function control panel; manual and electric slow-motion controls on both axes; keypad hand controller with digital readout display, permanently programmable Smart Drive, 9-speed drive controls on both axes (7-speed on 12"), High-Precision Pointing, and GO TO controller; 64,359-object onboard celestial software library; 25 ft. power cord and adapter for telescope operation from 115v.AC; 8 x 50mm viewfinder; 1.25" diagonal prism (7", 8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (7", 8", 10") or giant field tripod (12"); complete operating instructions.

8" LX200 Schmidt-Cassegrain	**$2495.**
10" LX200 Schmidt-Cassegrain	**2895.**
12" LX200 Schmidt-Cassegrain	**3995.**
7" LX200 Maksutov-Cassegrain	**2995.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 12"—$215; 7"—$125.

MEADE

LX50

Advanced technology at the most affordable prices ever.

- **Battery-Powered, Completely Cordless Operation!** Meade LX50 models operate for more than 50 hours from four AA-size batteries inserted through the telescope's control panel. Or use the standard-equipment 25 ft. cord to power the telescope directly from any auto cigarette lighter plug.

- **Standard-Equipment Declination Motor and Hand Controller:** Plug the hand controller into the LX50 control panel and you're ready for full dual-axis drive capability at any of 4 photo-guide or microslew speeds: 2x, 8x, 16x, or 32x, plus quartz-controlled sidereal-rate tracking in R.A. Switch speeds instantly using the speed-control button on the hand controller. Dual-axis drive rate is indicated by a red LED.

- **Multi-Function Control Panel:** Includes connectors for CCD autoguiders; for the standard-equipment Declination motor; and for the optional Magellan II Computer-Corrector *(below)*. A North-South switch permits telescope operation anywhere in the world.

- **Super Multi-Coated Optics:** The exact same EMC super multi-coated optical tube assemblies included with Meade LX200 models.

- **Massive LX200-type Fork Mounts:** Meade LX50 mounts are manufactured of the same virgin aluminum castings as Meade LX200 Schmidt-Cassegrains. Massive, rigid mountings that include the Meade LX worm-gear drive system with low periodic error for advanced photographic or CCD imaging applications. *No competing mid-priced equatorial mountings even come close.*

SPECIFICATIONS: 7", 8", and 10" LX50's—Each complete telescope includes 8" or 10" f/10 Schmidt-Cassegrain or 7" f/15 Maksutov-Cassegrain optical tube assembly with EMC super multi-coatings; heavy-duty LX200-type fork mount; 5.75" LX worm gear system in R.A.; multi-function control panel; DC servo Declination motor; manual and electric slow-motion controls on both axes; setting circles on both axes; keypad hand controller; 4-speed drive controls on both axes; battery compartment accepting four (user-supplied) AA-size batteries; 25 ft. power cord for telescope operation from 12v. auto cigarette lighter plug; 6 x 30mm (7" and 8" models) or 8 x 50mm (10") viewfinder; 1.25" diagonal prism; MA25mm multi-coated eyepiece (1.25"); standard equatorial wedge with elevation scale, bubble level, and azimuth control; complete operating instructions.

8" LX50 Schmidt-Cassegrain	**$1195.**
10" LX50 Schmidt-Cassegrain	**1495.**
7" LX50 Maksutov-Cassegrain	**1595.**
Variable-Height Field Tripod	**295.**
7" Maksutov-Cassegrain Tube Ass'y, only	**1195.**

Packing and shipping in the 48 states: 8"—$105; 10"—$145; 7"—$125; 7" Tube Assembly—$65.

8"
10"
7"
MEADE LX50 EMC

LX50 models shown with optional Field Tripod.

Meade Magellan™ II Computer-Corrector for LX50 Telescopes: Plug the Magellan II into the control panel of your LX50 and enjoy an incredible range of advanced capabilities. ■ Fast manual slewing to any object, either from input RA and Dec or from the 12,218-object database. ■ High-resolution 4096-pulse encoders (5.3 arc-minute precision), completely concealed in special LX50 encoder compartments. ■ Quick 2-star alignment. ■ Large 32-character, red-backlighted display. ■ 4-speed (2x, 8x, 16x, 32x sidereal) dual-axis drive corrector/microslewing system.

#2024: Magellan II for LX50's—Includes Magellan II hand controller *(right)*; encoders for both axes; all required mounting hardware. Installs to any LX50 in minutes. **$395.** + $15 packing and shipping in the 48 states.

Send $3.00 to Meade Instruments for the Meade 76-page General Catalog. Prices shown are suggested U.S. mail-order retail prices.

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February 1996
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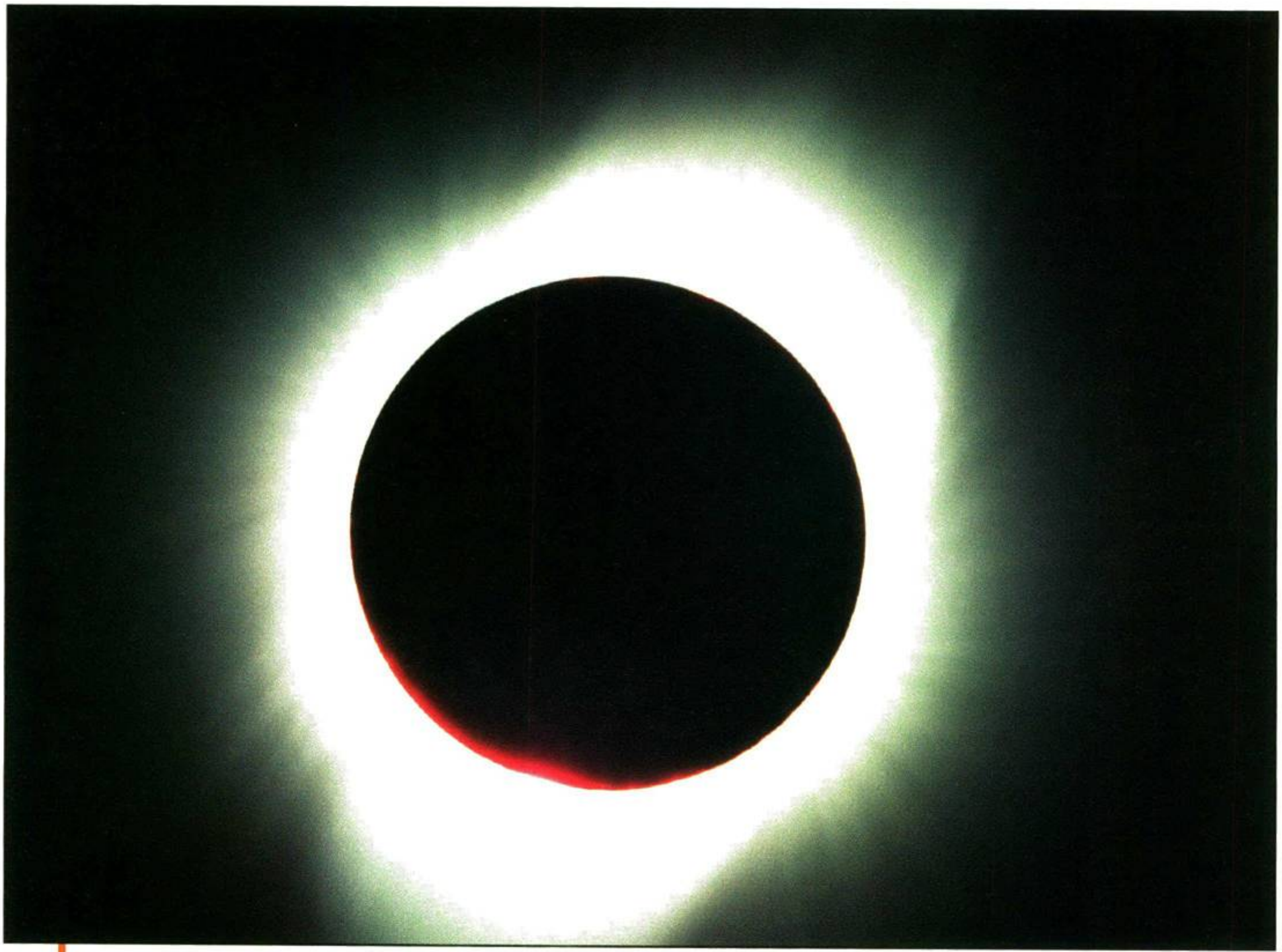

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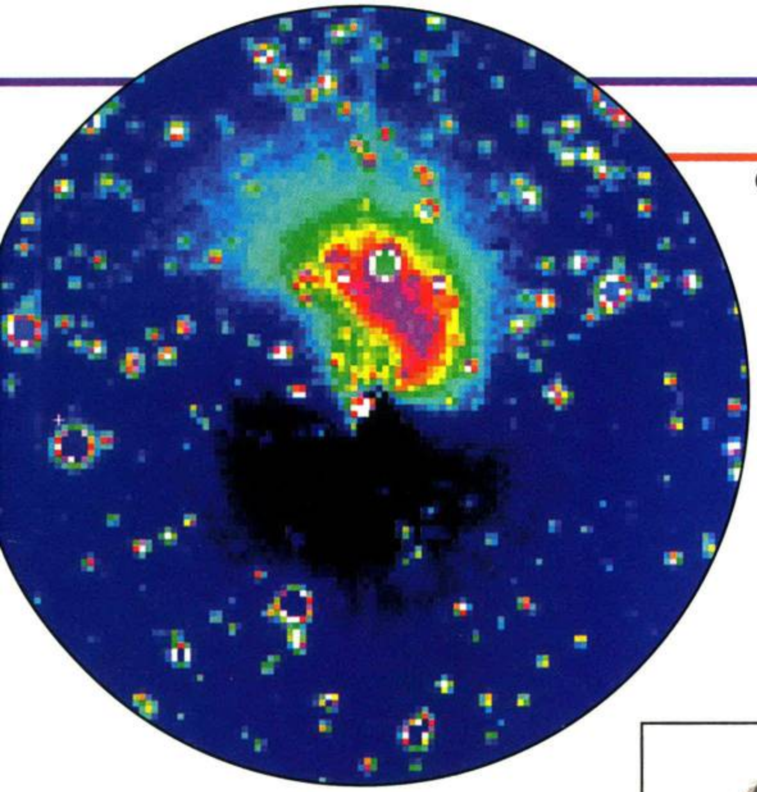
SHADES OF THINGS TO COME? Comet de Vico (seen here) put on an impressive display in late 1995, however, it may pale next to the upcoming Comet Hale-Bopp. For details on what could be the "comet of the decade," see page 68. Photo by Michael Stecker.



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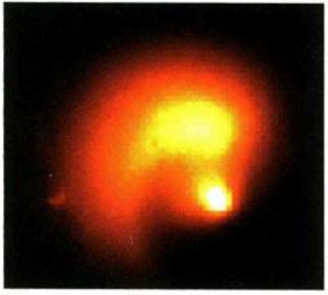
BEHIND THE SCENES

Get Ready for Hale-Bopp

Finally! It's about *time* that a bright comet came along! Like most people who've been skywatchers for a while, I'm looking forward very much to the arrival of Comet Hale-Bopp. It's at magnitude 9.5 right now — although being in Sagittarius it's lost in the glare of the Sun. But it will emerge in the morning sky in early March and brighten steadily throughout 1996. It should be magnificent a year from now.

The lengthy apparition means that for backyard astronomers, Hale-Bopp is going to become Old Reliable. As it sweeps in toward the solar hearth, we'll see it slowly brighten. Feeling the warmth of the Sun's rays, Hale-Bopp will likely develop an intricate coma, as jets and eruptions on its dirty-snowball nucleus feed its dust and gas tails. These will grow large and distinct from each other, and perhaps we'll see pieces of the gas tail develop knots and break off, like a tattered flag disintegrating in a hurricane.

STScI



Comet Hale-Bopp, October 5, 1995

The last comet that performed really well for Northern Hemisphere dwellers was Comet West, back in 1976. True, a decade ago Halley produced its famous periodic show. But orbital circumstances made Halley a disappointment for the general public and underwhelming even for many experienced backyard astronomers.

Hale-Bopp should do a lot better, for us and for the public. On page 68 of this issue, you'll find a complete guide to the comet's coming apparition.

And therein lies a challenge. You and I will clearly enjoy the coming sights. But what about our non-astronomer friends and neighbors? They'll need some help and guidance. Wouldn't it be outstanding if every amateur astronomer made a point of using this comet's arrival to turn people on to the joys and rewards of skywatching?

Nature has sent us a splendid opportunity — let's make good use of it.

Sincerely,

Robert Burnham

Robert Burnham
Editor
rburnham@astronomy.com

LETTERS

Long Live Halide

I was struck by Robert Burnham's editorial "Photography Rediscovered" (November 1995). For some time I've claimed that rumors of the death of conventional, film-based astrophotography are not to be believed. Despite all the arguments about CCDs being "better" than conventional film, the fact that CCD imaging is tremendously expensive can't be overlooked.

As chairman of the Astrophoto Special Interest Group in the Texas Astronomical Society of Dallas, I talk with many beginning club members. Nothing's more frustrating than hearing one say, "I would like to do astrophotography, but people tell me film is dead, and I don't want to spend $2,000 on a CCD camera." I quickly tell them they can create beautiful pictures on film with only a modest investment.

I, for one, will not be converting my darkroom into a closet — at least not yet. — *Jason Ware, Frisco, Texas, jware@galaxyphoto.com*

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U.S. and International Newsstand Distribution
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Canadian Newsstand Distribution
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ASTRONOMY is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Editorial phone: (414) 796-8776; advertising: (800) 558-1544; customer service: (800) 446-5489; subscriptions: (800) 533-6644 7 days a week, 24 hours a day; fax (414) 796-0126. Copyright © 1996 Kalmbach Publishing Co., all rights reserved. Material in this publication may not be reproduced in any form without permission. Second-class postage paid at Waukesha, WI, and additional mailing offices. Allow 6 to 8 weeks for new subscriptions and address changes. Subscription price: 1 year $34.95. Canadian and foreign: 1 year $45, GST (#R122713209) included; please remit in U.S. funds. Not responsible for unsolicited materials. POSTMASTER: Send address changes to ASTRONOMY, 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187. Canadian second-class postal permit no. 545775. *Printed in the U.S.A.*

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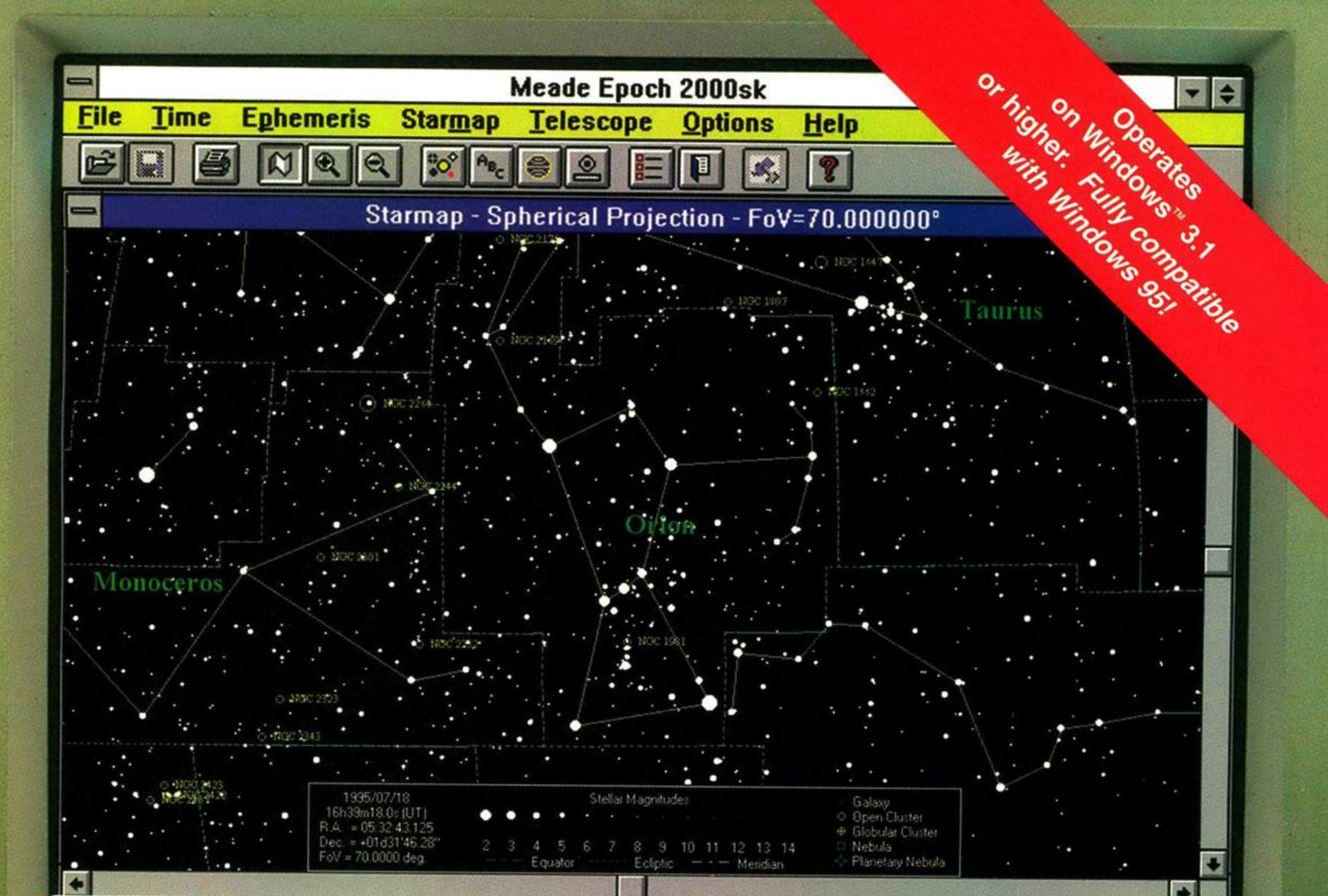
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Open Cluster
Globular Cluster
Nebula
Planetary Nebula

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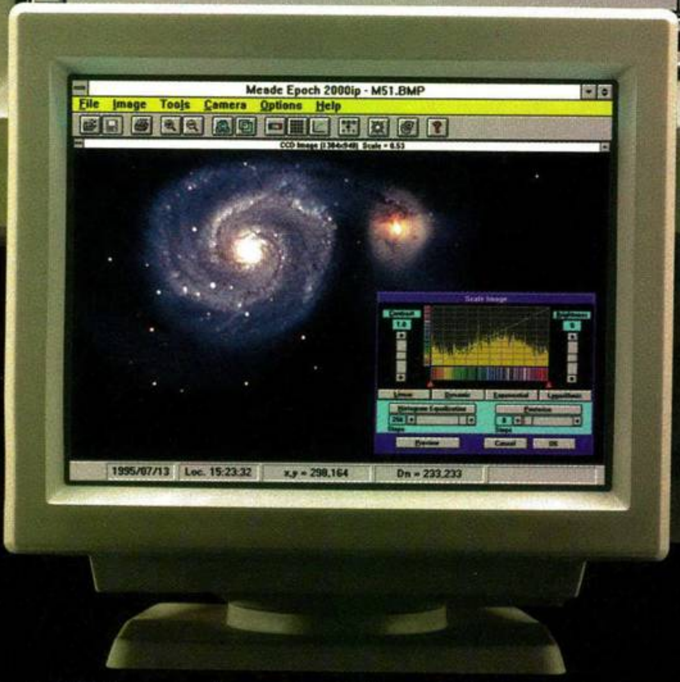
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#140: The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

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52°

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56mm (52°; 2")		**229.95**	(5.48)

Series 4000™ f/6.3 Focal Reducer/ Field Flattener

f/6.3 FOCAL REDUCER/FIELD

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

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Series 4000™ Ultra Wide Angle 84°

The ultimate eyepieces; extreme image sharpness over an amazing 84° field.

Ultra Wide Angle (UWA; 8-elements; 1.25"; 84°)–**4.7mm: $179.95** (3.29); **6.7mm: 219.95** (3.29); **8.8mm** (1.25"/2"): **269.95** (4.78); **14mm** (1.25"/2"): **329.95** (5.48)

Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

.965": $27.95; **1.25": $29.95** (2.98)

Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

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Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

$39.95 (2.98)

T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

$26.95 (2.98)

Meade Model 285 60mm f/15 Equatorial Refractor

Complete with tripod and 2 eyepieces.

Includes the same equatorial mount of larger Meade models at right. Dual-axis worm-gear slow-motion controls permit easy tracking of astronomical objects. Two eyepieces (1.25") for powers of 36X and 100X. Multi-coated objective lens resolves to the theoretical limit.

Accepts #531 Motor Drive *(below)*

$299 (16.55)

Meade Model 4500 4.5" f/8 Equatorial Reflector

World's largest-selling 4.5" telescope!

The finest first-telescope available. *Provides stunning optical performance on the Moon, planets, and hundreds of deep-space objects.* Precision equatorial mount includes worm-gear slow-motion controls in RA and Dec and full-length (50") aluminum tripod. 6 x 30 finder, rack-and-pinion focuser (1.25"), multi-coated MA 25mm eyepiece (1.25"). *Immediate delivery through your authorized Meade dealer.*

Fully automatic tracking with #531 Motor Drive *(below)*

$399 (22.40)

Meade Model 390 90mm f/11 Altazimuth Refractor

Perfect for land-viewing or astronomy.

Excellent imaging power for any terrestrial application, or for observing hundreds of astronomical objects in sharp detail. Smooth dual-axis controls; multi-coated optics. Supplied with 6 x 30 finder, MA25mm eyepiece (1.25"), aluminum tripod.

Includes flexible steel cable controls on both axes.

$499 (23.60)

Meade Model 395 90mm f/11 Equatorial Refractor

Multi-coated, high-resolution optics.

Includes flexible steel cable controls on both axes.

Accepts #531 Motor Drive *(below)*

Precision Meade objective lens far surpasses other telescopes selling at similar prices. Complete with equatorial mount, aluminum tripod, 6 x 30 finder, MA 25mm eyepiece (1.25"). Thousands now in use.

$599 (24.65)

Meade intermediate-size telescopes are the world's largest-selling quality telescopes of their apertures. *They are the only telescopes in this price range designed by Meade engineers and manufactured to exclusive Meade specifications.* Each instrument includes mechanical components, gear systems, and accessories specifically intended for serious applications of the beginning to intermediate amateur astronomer. American-size 1.25" barrel-diameter eyepieces, threaded for filters, are included with all models. Large cable controls facilitate the tracking of astronomical or terrestrial objects, and, on equatorial models, the optional Meade #531 Motor Drive *(see right)* enables fully automatic tracking of astronomical objects.

#531 Motor Drive

Attaches in seconds to the equatorial mounts of Meade Models 285, 4500 or 395 telescopes. Permits fully automatic tracking of celestial objects. Cordless operation anywhere in the world from 3 (user-supplied) AA batteries.

$99.50 (4.78)

Series 3000™ Plössls 50°

The very latest in eyepieces from Meade optical designers, new Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Available in a wide range of focal lengths from 5mm through 25mm. All five eyepieces are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. Manufactured exclusively for Meade Instruments by one of Japan's leading lensmakers, Series 3000 Plössls produce excellent results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

Series 3000 Plössls (4-elements; 1.25"; 50°)

5, 6.7, 9.5, 16, 25mm each: **$49.95** (3.45)

Series 3000™ Plössl 40mm 44°

A perfect complement to the Series 3000 Plössls at left, this all-new Plössl 40mm produces spectacular low-power, wide-field results with any telescope. Includes classical 4-element Plössl optics, multi-coated. Barrel dia. 1.25"; threaded for filters. Apparent field: 44°.

$79.95 (3.79)

MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Wireless red LED illuminator and variable brightness control. **Batteries included.**

$99.95 (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator. **$79.95** (3.45)

Modified Achromatic Eyepieces

Meade 3-element MA eyepieces yield sharp, well-corrected images on the Moon, planets, and deep-space at a reasonable price. Multi-coated; threaded for filters; 1.25" barrel diameter. Apparent field: 40°. **MA 9, 12, 25, 40mm.**

each: **$37.95** (2.98)

HOW TO ORDER

- Prices shown are suggested USA mail-order retail prices and do not include any applicable sales taxes.
- Suggested shipping and handling charges to the 48 states by UPS or US Mail shown in ( ) next to each price.
- Meade accessories may be ordered from any Meade Advanced Products Dealer. **The following national mail-order dealers carry all Meade accessories in-stock for immediate shipment:**

ASTRONOMICS, Norman, OK.
Orders: 800-422-7876; Info.: 405-364-0858.

CALIFORNIA TELESCOPE CO., Burbank, CA.
Orders & Information: 818-505-8424.

CITY CAMERA, Dearborn, MI.
Orders: 800-359-5085; Info.: 313-846-3922.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Info/IL: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

2x-3x Variable Barlow (1.25")

#127: Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

$59.95 (3.45)

2x Short-Focus Barlow (1.25")

#126: Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, at right. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

$47.95 (3.45)

2x Telenegative Barlow (1.25")

#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

$47.95 (3.45)

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FREE! $800 CCD Equipment System!

Now, for a limited time, when you purchase a Meade Pictor 416 or 1616 CCD imager at the regular price, **we'll include an $800 Meade CCD Equipment System—everything you need for advanced CCD imaging—absolutely FREE!** Purchased separately, the CCD Equipment System is priced at $807 and includes these important products:

Meade Pictor 201 Autoguider: Allows completely automatic guiding of your Pictor camera during CCD imaging or your 35mm camera during long-exposure astrophotography.	**$395.**
Meade CCD Off-Axis Guider System: Complete with adapters for 1.25" eyepiece holders and for Schmidt-Cassegrain rear-cell threads. Use with the Pictor 201 on guide stars to 10th-magnitude.	**119.**
Meade CCD Image-Orientation Adapter: Threads into the Off-Axis Guider and permits precise image orientation on the CCD chip.	**35.**
Meade Epoch 2000ip Image Processing Software: Professional Windows-based image processing that permits the enhancement and analysis of CCD images using the most advanced techniques, including dynamic scaling, histogram equalization, image convolution, unsharp masking, median filtering, RGB merging, and more.	**199.**
Meade Foam-Lined Carrying Case (19" x 14" x 7"): Provides for secure storage and transport of your Pictor 416 or 1616 CCD imager as well as all items of the CCD Equipment System described above.	**59.**
Total price of all items if purchased separately:	**$807.**

The Meade Pictor 416 CCD Imaging Camera is packed, at no additional charge, with the **Meade $800 CCD Equipment System** during the period of this special offer.

EPOCH 2000
EPOCH 2000
MEADE
PICTOR
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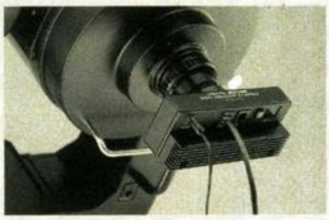
PICTOR
MEADE PICTOR
CCD AUTOGUIDER
Meade
OFF-AXIS GUIDER

The Trifid Nebula (M20): Pictor 1616; a 5-minute exposure by Jack Newton with the Meade 7" f/9 *ED* Apochromatic Refractor.

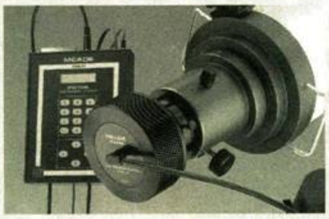
Pictor 201 Autoguider: For flawless, ultraprecise autoguiding during long-exposure astrophotography or CCD imaging. Automatically locks on to guide stars as faint as 10th-magnitude and makes all required dual-axis corrections. Results in perfectly guided astrophotographs or CCD images during even the longest of exposures. Completely self-contained; no host PC required. **$395.** + $10 packing & shipping in 48 states.

Pictor 208 Autoguider/Imager: For an amazingly low price, the 208 gives impressive imaging capability even to the novice. On telescopes of 4" aperture and larger, the Pictor 208 yields very satisfying results and, in addition, is a full-capability autoguider, containing the exact same autoguider hardware and software as the Pictor 201, above. The 208 incorporates the Texas Instruments TC-255 microchip, by far the largest, highest-resolution chip available in any CCD unit in its price range. **$795.** + $15 P & S



Pictor 216 CCD Autoguider/Imager: Identical in operation and size to the 208, the Pictor 216 includes a 16-bit A/D converter for 65,536 brightness levels. The result is a level of image quality only obtainable on competing units that sell for almost twice the 216's price. Combining high-resolution imaging with low dark current, the Pictor 216 satisfies the long-term CCD imaging requirements of the majority of serious amateurs. **$1295.** + $15 P & S

Pictor 416 CCD Autoguider/Imager: Armed with the powerful Kodak KAF-0400 CCD microchip, the Pictor 416 is the most advanced high-resolution CCD system available under $5000. And, with its standard-equipment SCSI interface, the 416 can full-frame download in *one second!* The Pictor 416 is a powerful CCD system on any telescope; attached to a Meade LX200, its capabilities are truly awesome. The auto-mosaic feature, for example, permits the imaging of an arbitrarily large sky area **automatically** on user command. **$2495.** + $25 P & S



Pictor 1616 Autoguider/Imager: For professional-level applications the Pictor 1616 utilizes the Kodak KAF-1600 microchip, one of the largest (13.80 x 9.20mm) CCD chips in commercial production. Identical in pixel density and dark current to the 416, but with *four times* the chip area, the 1616 permits the imaging of very large sky areas: a sky area of 23' x 15' with an 8" f/10 Schmidt-Cassegrain, almost one-half the lunar surface in a single exposure. The 1616 is the finest CCD imaging system available at under-$10,000. **$6495.** + $40 P & S

The special Meade CCD Equipment System offer is effective beginning July 20, 1995, at participating Meade dealers in the U.S.A. and Canada. *This offer is valid until further notice and may be withdrawn at any time.* ■ All prices shown are suggested U.S. national mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable. ■ For safety reasons AC-powered personal computers should be used indoors only. ■ The Meade brochure ***CCD Imaging Made Simple*** is available free of charge, or send $3.00 for the 76-page Meade ***1995 General Catalog.***

AUTHORIZED U.S. MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK, Orders: 800-422-7876; Information: 405-364-0858

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Orders & Information: 818-505-8424

CITY CAMERA, Dearborn, MI, Orders: 800-359-5085; Information: 313-846-3922

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LUMICON, Livermore, CA, Orders: 800-767-9576; Information: 510-447-9570

SHUTAN CAMERA & VIDEO, Chicago, IL, Orders: 800-621-2248;
Illinois & Information: 312-332-2000

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EFSTONSCIENCE, Toronto, Ontario, Orders & Information: 416-787-4581

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16" f/4.5
$1095.
12" f/4.8
$795.
8" f/6
$425.
10" f/4.5
$595.
6" f/8
$325.
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Dobsonian telescopes with quality Meade® optics and components — at a fraction of the price you'd expect to pay.

All models shown with optional #637 6 x 30mm or #545 8 x 50mm viewfinders.

Compare *feature-for-feature* with other similarly priced Dobsonians!

■ **Primary and Secondary Mirrors of Low-Expansion Pyrex® Glass:** Unlike the plate glass optics of other Dobsonians that can become thermally unstable (especially in larger apertures), Meade Dobsonians are made of Grade-A, fine-annealed Pyrex—the exact same professional-quality optics used on Meade Starfinder Equatorials.

■ **Precision Components:** Including a full-size rack-and-pinion focuser (1.25") with 2.6" travel and fully-adjustable *4-vane* secondary mirror system.

■ **Rigid, Durable, Beautiful Dobsonian Mountings**, manufactured of cabinet-quality materials, provide extremely smooth motions of the telescope in both altitude and azimuth. Both telescope axes ride on zero-backlash Teflon/Nylon bearings, facilitating the location and tracking of celestial objects.

■ **Optical Tubes:** Starfinder Dobsonians include the same strong, spiral-wound optical tubes used on Starfinder Equatorials *(right)*. All telescopes include a multi-coated MA25mm eyepiece; each tube is factory pre-drilled for the optional 6 x 30mm or 8 x 50mm viewfinder.

■ **Performance!** A Meade Starfinder Dobsonian or Equatorial opens *up the skies* to an extremely wide range of serious visual observing: all 110 Messier objects, thousands of NGC objects—nebulae, galaxies, star clusters, in all their variations of form, color, and extent, as well as the Moon and planets in stunning, high-resolution detail. Starfinder Dobsonians are telescopes for visual observing; motor-driven Starfinder equatorials may be used, in addition, for lunar and planetary photography and even for limited deep-space photography.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$39; 8"–$49; 10"–$69; 12.5"–$79. 16"–$45 packing, shipped truck freight collect.

ACCESSORY OFFER!

At the time you order any Meade Dobsonian, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, *and* the Meade #637 6 x 30mm viewfinder with metal bracket for a **total of $49.95!** *Purchased separately, the 2 eyepieces and viewfinder sell for $125.85!* Offer valid until further notice.

AUTHORIZED U.S. MAIL-ORDER DEALERS

ASTRONOMICS, Norman, OK.
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CALIFORNIA TELESCOPE COMPANY, Burbank, CA.
Orders & Information: 818-505-8424.

CITY CAMERA, Dearborn, MI.
Orders: 800-359-5085; Info.: 313-846-3922.

FOCUS CAMERA, Brooklyn, NY.
Orders: 800-221-0828; Info.: 718-436-6262.

LUMICON, Livermore, CA.
Orders: 800-767-9576; Info.: 510-447-9570.

SHUTAN CAMERA & VIDEO, Chicago, IL.
Orders: 800-621-2248; Illinois & Info.: 312-332-2000.

Canada:

EFSTONSCIENCE, Toronto, Ontario.
Orders & Information: 416-787-4581.

KHAN SCOPE CENTRE, Toronto, Ontario.
Orders & Information: 416-783-4140.

STARF
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Computerize your Meade® Starfinder™ Dobsonian or Equatorial for only $295!

Spend your time **observing, not searching** for objects! **With the incredible Meade Magellan™ Telescope Computer System** attached to your Meade Starfinder Dobsonian or Equatorial, finding any of **12,218 celestial objects** is almost as easy as pointing the telescope.

■ Don't spend $400, $500, or $600 for a computer system with fewer features! Designed and manufactured at the Meade Irvine facility, the Magellan I includes one of the largest object databases available, incorporates only premium-grade components, and sells for a low $295!

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ENTER
MODE
PREV
NEXT
ON
MAGELLAN I
TELESCOPE COMPUTER SYSTEM
U.S.A.

Actual Size: 4" x 5" x 1.25"

■ **Easy to Use!** Just input the R.A. and Dec. of the object you wish to observe, or call up an object from Magellan's massive database. Magellan allows you to slew the telescope manually to the object and place it in the visual field, quickly and precisely.

■ **Fast 2-Star Alignment:** Point the telescope at 2 bright stars selected from the star database, and the computer is aligned in *seconds.* No need to input time or date, latitude or longitude. Magellan's powerful microprocessor calculates telescope position in milliseconds and directs your movements of the telescope for fast, accurate object location.

Meade Magellan II Computer-Corrector for Starfinder Equatorials

Plug the Magellan II into the control panel of your Meade DC-powered Starfinder Equatorial *(right)* and you have *all the capabilities of the Magellan I (above)* ***plus*** a 4-speed, dual-axis, drive-corrector/microslewing system!

Includes: Magellan II hand controller *(right)* with 4 dual-axis speed rates (2x, 8x, 16x, 32x sidereal); high-resolution 4096-pulse encoders for both axes; electric Declination control system; 12,218-object computer database; 2-star alignment; RS-232 serial interface. (For Meade *DC-powered* Starfinder Equatorials, only.)

#2018: for Starfinder Equatorial
6", 8", or 10" . . . . $495.
#2019: for Starfinder Equatorial 16" . . . 595.

Prices plus $20 packing & shipping in the 48 states.

INDER
UTERS

■ **High-Resolution 4096-pulse Encoders:** Each Magellan system includes two premium-grade, high-resolution encoders. Encoder precision is 5.3 arc minutes.

■ **Large 32-Character LCD Red-Backlighted Display:** The same LCD display included with the Meade LX200 hand controller. Includes variable illumination from dim to bright.

■ **12,218-Object Database:** A database that includes an amazing array of objects:

7,840	NGC objects; the complete NGC catalog
4,093	IC objects from the Index Catalog
125	user-defined objects
110	Messier objects; the complete catalog
42	alignment stars for the Magellan system
8	major planets, from Mercury to Pluto
12,218	objects, total

■ **Supplied Complete!** With other computers you pay *once* for the basic controller and then pay *again* for the "Encoder Installation Package." Meade Magellan Systems are supplied **complete** with: controller/display unit (4" x 5" x 1.25"); encoders for both telescope axes; RS-232 serial interface; bracket for convenient placement of the controller on the telescope tube; and attachment hardware. Just add the user-supplied 9v. transistor radio battery, and Magellan is ready to use. First-time installation is quick and simple.

Meade Magellan I Telescope Computer Systems

#2010:	**for Meade Starfinder Dobsonian 6", 8", 10", 12.5", or 16"**	**$295.**
#2011:	**for Meade (DC-powered) Starfinder Equatorial 6", 8", or 10"**	**295.**
#2012:	**for Meade (DC-powered) Starfinder Equatorial 16**	**295.**

All prices plus $15 packing & shipping in the 48 states. Prices shown are suggested U.S. national mail-order retail prices. For additional information on Meade Magellan systems, send for your free copy of **Meade Bulletin 2900.**

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MAGELLAN II
COMPUTER - CORRECTOR
ENTER
MODE
FIND
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STAR 6
16X 4
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CNGC 3
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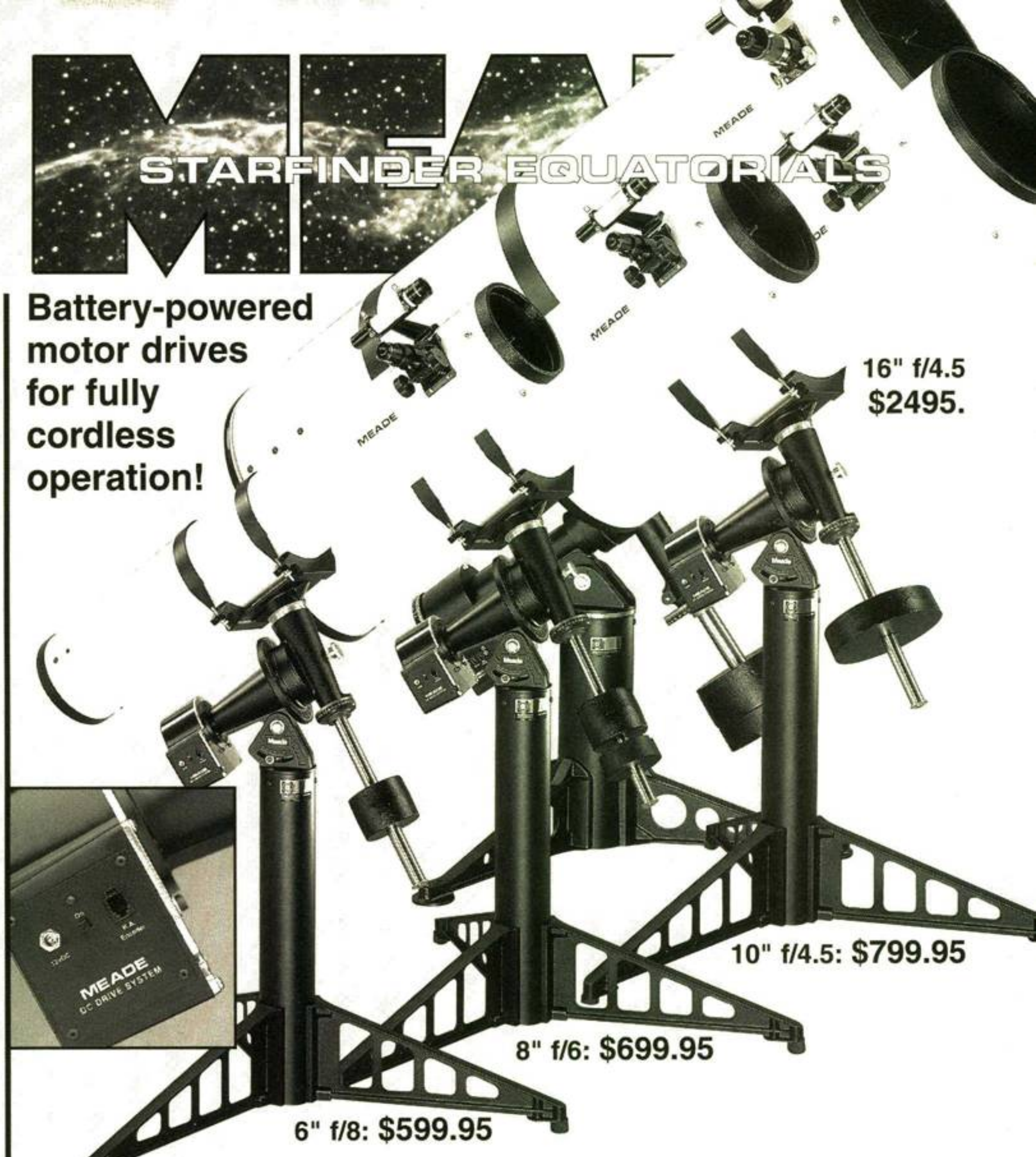
U.S.A.



Battery-powered motor drives for fully cordless operation!

Standard equipment on 6", 8", and 10" equatorial models includes:

■ **Superb Optical System:** Includes hand-figured, parabolic primary mirror and elliptical flat secondary, both of Grade-A Pyrex glass. Optics are multi-coated and meet the theoretical limits of resolution.

■ **Precision Equatorial Mount:** Manufactured of machined aluminum to tolerances of .001" or better, with 4"-dia. pier and die-cast tripod legs for rock-solid support of the optical tube. Moves effortlessly from object to object on precision bearing surfaces. Polar and Dec. shafts are 1" solid steel. Setting circles on both axes.

■ **Battery-Powered Cordless Drive System!** Provides fully automatic tracking of celestial objects. Operates for more than 50 hours from 4 (user-supplied) AA-size batteries inserted through the drive cover. Control panel *(see inset, above)* also permits powering of telescope from 12v. auto cigarette lighter plug, using optional 25' cord.

■ **Accessories and Components:** Rack-and-pinion focuser (1.25") with 2.6" travel; #637 6 x 30mm viewfinder; multi-coated MA25mm (1.25") eyepiece; strong, durable, spiral-wound optical tube with attractive white finish.

■ **Starfinder Equatorial 16:** Includes equatorial mounting with 1.5" steel shafts, Sealmaster ball bearings, 6"-dia. pier, 4 x AA-size battery-powered worm gear drive, 8 x 50mm viewfinder, #682 giant (2" & 1.25") rack-and-pinion focuser.

Packing and UPS Shipping Charges to any address in the 48 states: 6"–$65; 8"–$75; 10"– $90. 16"–$55 packing, shipped truck freight collect.

To Order: Contact your authorized Meade Advanced Products Dealer. All prices shown are suggested USA mail-order retail prices.

Meade 1995-96 General Catalog, $3.00 postpaid, is available from your authorized Meade dealer or directly from Meade Instruments.

ACCESSORY OFFER!

At the time you order any Meade Starfinder Equatorial Telescope, you can buy 2 additional multi-coated eyepieces, MA9mm and 12mm, for a **total of $29.95!** *Purchased separately, the 2 eyepieces sell for $75.90!* Offer valid until further notice.

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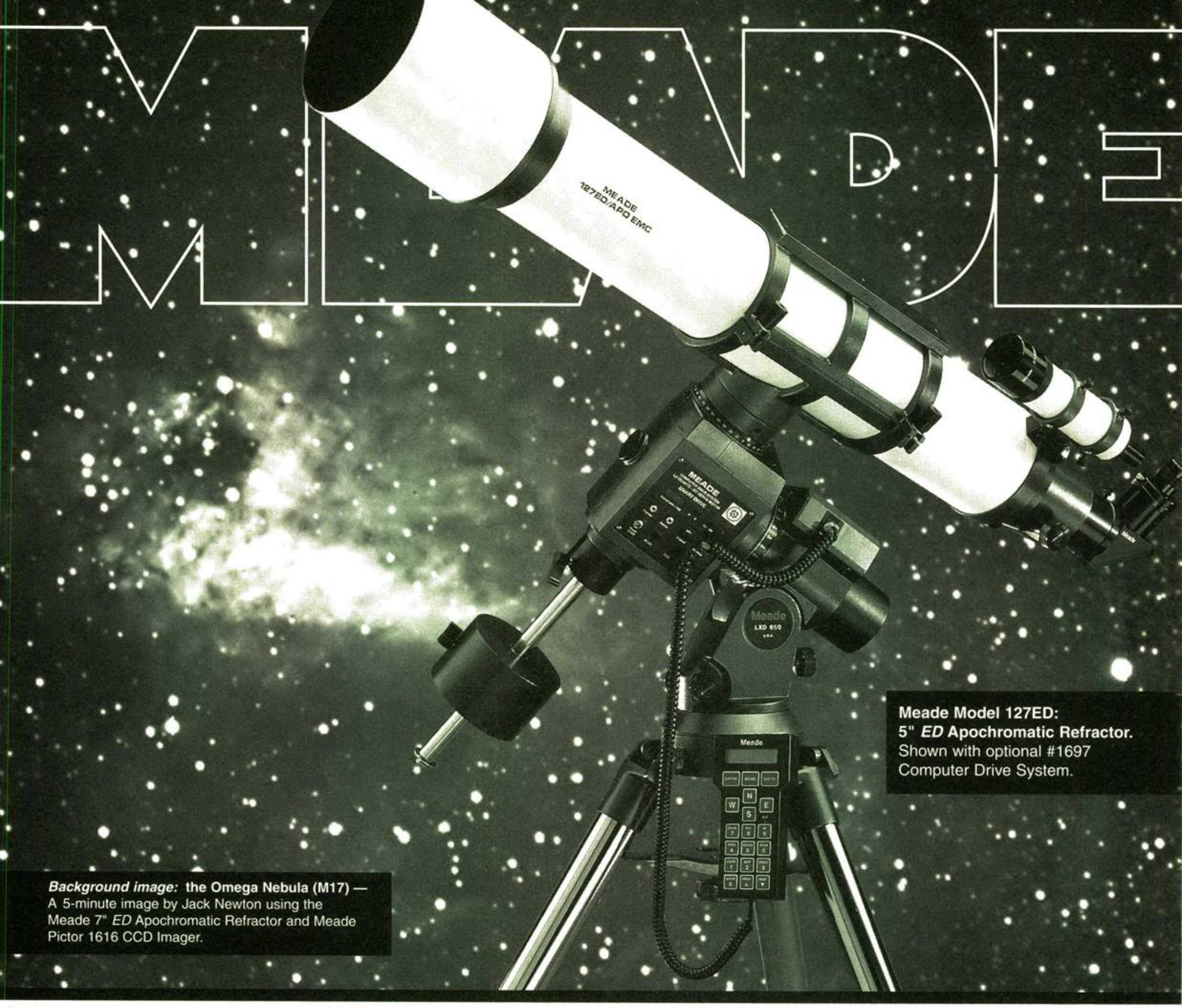

Meade Model 127ED:
5" *ED* Apochromatic Refractor.
Shown with optional #1697 Computer Drive System.

Background image: **the Omega Nebula (M17) —**
A 5-minute image by Jack Newton using the Meade 7" *ED* Apochromatic Refractor and Meade Pictor 1616 CCD Imager.

ED APOCHROMATIC REFRACTORS

"This is the best black-and-white CCD image of M17 that I have ever taken with any telescope. I just couldn't believe that this could be done in a 5-minute shot with a CCD camera and a 7" refractor. I'm amazed at how the telescope performs, even against my own 25" Newtonian." **—Jack Newton**

Fortunate indeed is the observer with a Meade *ED* Apochromatic Refractor at his or her disposal, for these are professional-class instruments capable of serious research. Observe structural detail and color variations within Jupiter's Red Spot and at the boundaries of 8 to 10 cloud belts; resolve all three of Saturn's main rings and substructures within the rings themselves. *Simply put, if you're looking for the finest, textbook-perfect, ultra-high-resolution, high-contrast imaging of the skies that astronomical instrumentation, of any type, can provide, then a Meade ED Apochromatic Refractor is for you.*

Use the massive Meade **LXD 650** (4", 5") or **LXD 750** (6", 7") equatorial mounts in conjunction with the optional **#1697 Computer Drive System** to slew the telescope across the sky and computer-point the instrument, automatically, *to a precision of one arc-minute.* ***Meade LXD mounts are the only commercially-available German-type mounts capable of such a feat.*** Actuate any of 9 pushbutton-controlled drive speeds (from 2x photoguide to 8°/sec. fast-slew) on both axes, automatically, to locate and center any object directly from its input R.A. and Dec. Or use the onboard database for even faster object centering. Included with the #1697 CDS, the Meade **Smart Drive**™ assures the extremely low periodic error essential to research-level photographic or CCD imaging.

More than 40 Meade optional accessories are available to suit virtually any observing, photographic, or CCD imaging requirement.

Supplied complete per catalog specifications:

4" f/9 Model 102ED	**$2495.**
5" f/9 Model 127ED	**2995.**
6" f/9 Model 152ED	**4495.**
7" f/9 Model 178ED	**5495.**
#1697 Computer Drive System	**695.**

Packing and shipping in the 48 states: 4"—$105; 5"—$125; 6"—$185; 7"—$215.

MEADE
MEADE LX200
MEADE LX200
MEADE LX200 EMC

16" LX200

Professional instrumentation for the demanding school, college, or university research program—or as the ultimate personal telescope for the advanced amateur.

Professional-grade 16" f/10 optical system meets or exceeds advanced requirements; includes BK7 correcting plate for high UV transmission and EMC super multi-coatings. ■ **Massive one-piece fork mount** permits substantial auxiliary equipment to be piggybacked with rock-solid stability. ■ **Large 11" worm gears** on both axes, with factory-programmed Smart Drive™; periodic error less than 5 arc seconds. ■ **Automatic GO TO capability** to any object in the onboard 64,350-object database or to any input R.A. and Dec. ■ **High-Precision Pointing™** to within one arc-minute in the GO TO mode. ■ **DC servo drive systems** with integrated encoders and planetary gearboxes; encoder resolution: 0.13 arc secs. ■ **Six pushbutton-controlled drive-speed rates,** from photo-guide to fast-slew on both axes, simultaneously. ■ **Micro-processor controlled sidereal-rate tracking** in AZ or EQ modes with quartz accuracy. ■ **Home-Pulse Acquisition** permitting remote alignment and operation through a modem link to the telescope's RS-232 interface. ■ **Control panel connectors** for optional systems including CCD autoguiders and imagers, electric focuser, and the Meade **#1222 Field De-rotater** for long-exposure astrophotography in the AZ mode. ■ Available with **supergiant transportable field tripod** (2-person field set-up in less than 10 minutes); **permanent altazimuth pier** (permitting the entire instrument to be housed in a 2-meter dome); or **permanent equatorial pier** (in cases where piggybacked astrocameras do not permit field de-rotation).

The Meade 16" LX200 is in continuous production at the Meade Irvine, Calif. factory. **Delivery time:** 4 to 12 weeks. **Price:** $14,950, complete with supergiant field tripod, plus $385 packing and shipping in the 48 states; prices slightly higher with permanent altazimuth or equatorial pier.

For your copy of the all-new **1995 Meade General Catalog** ($3.00), write Meade Instruments or contact your authorized Meade Advanced Products Dealer.

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Get the most viewing pleasure with top-rated
BINOCULAR GUIDERS
Eliminates tripod hugging, arm fatigue, unsteady viewing ★ Views from zenith to horizon, 360° in azimuth ★ Smooth action ★ Three adjustable brakes ★ Heavy construction ★ Weighs 7 lbs. ★ Mounts on standard tripod
For 60mm binoculars & under **$140**
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BINOCULAR OBSERVING CHAIR
★ Rotates 360°, views from zenith to horizon ★ Easily adjusts to observing positions ★ Tension adjustment for binocular sizes ★ Safety wheel promotes steadiness ★ Back removes for transportation ★ Weighs 35 lbs.
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NEW!
MICROSTEPPING TELESCOPE CONTROLLER
★ High performance tracking system with **FAST SLEW** for ultimate control.
$1600-$2100

Astrophotography at an affordable price!
CAMERA TRACKERS
CHOOSE FROM THREE MODELS
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VISTA DRIVE CORRECTORS
JP400 / 500 Series—**$325-385**
★ Designed to drive Meade, Schaefer, Byers, Celestron C-14, etc., with high precision, resolution and accuracy ★ Available with options for SBIG, single or dual axis interfacing and 240 VAC, 50 Hz foreign operation ★ Synchronous and stepper systems
Other systems available from **$125-$1500**

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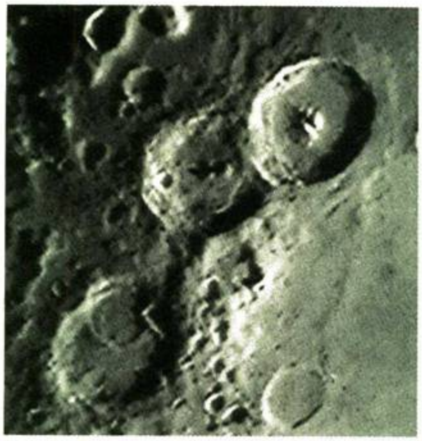
For free brochure call (805) 925-1240.
For full line catalog send $2.00 to VISTA INSTRUMENT CO.,
P.O. Box 1919-A, Santa Maria, CA 93454.

LETTERS

Shooting the Moon

My father and I enjoy ASTRONOMY greatly. We especially watch for the Moon Observer's Notebook and like imaging the lunar surface ourselves. We use a chip designed for video cameras that monitor shopping centers. With a PAL connection, the chip connects to a television or a VCR. We mounted this chip onto an 8-inch SCT. I enclose a picture of the Aristoteles and Eudoxus region, which we saved, frame-grabbed, converted to a postscript file, and printed on a 600 dpi laser printer.



Aristoteles and Eudoxus

Eva-Maria Reinecke

We hope you will enjoy this picture and share it with your readers. — *Eva-Maria Reinecke, Neunkirchen am Brand, Germany*

Theophilus, Cyrillus, and Catharina

Eric J. Douglass

Regarding "Are the Best Lunar Photographers French?" (July 1995), I would say the real question is not, Who takes the best lunar photographs? but Who takes the best with a certain size scope, the type of imaging equipment used, and the limiting factors of the local environment?

I use a 4-inch refractor and observe near sea level, so I can not match the resolution of a 12-inch Cassegrain in the mountains. Still, I take the best lunar images with a 4-inch scope where I live.

I include photographs of mine on display at the Morehead Planetarium at the University of North Carolina at Chapel Hill. To take them, I used a Burle TC650 video camera, a 4-inch refractor, ran the signal through a Videonics video processor, and recorded the images in SVHS format. I printed them on a Sony video graphic printer.

I contend that excellent lunar photos can be taken anywhere with any size scope, and that I have the best in the 4-inch range. — *Eric J. Douglass, Sanford, North Carolina*

Is Anyone Down There?

The aerial view of North America from space ("How to Beat Light Pollution," September 1995) reminds me of a similar photo and what it prompted me to do several years ago.

A glance shows that many of the city lights appear to be on "lines" radiating from the areas of brightest light. I overlaid a copy of such a photo onto a map and found a strong match between the "lines" on the satellite image and the interstate highway system. My suspicion is that this is a fairly recent trend. Checking satellite photos from the 1960s, 1970s, and 1980s should enable tracking the growth of this highway-related light. — *Steve Dikkers, Guttenberg, Iowa, SteeDee@aol.com*

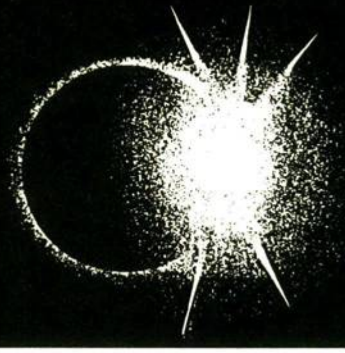
Balancing a Dob

In the January 1993 issue of ASTRONOMY, I suggested placing the vinyl dust cover of a Dobsonian telescope over its rear end to balance finder scopes and/or heavy eyepieces. But the vinyl cover can become stiff in the cold of winter.

Since then, we have seen the introduction of velcro strips and beanbags. I now offer the simplest and least expensive solution: Strap an adjustable lap pack or fanny pack around the rear end of the telescope tube. Fill the zipper pockets with any household objects needed to balance the load. Tools or metal spoons work especially well. — *Bryan Stone, Chelmsford, Massachusetts*

A Regional Bludgeon in Your Future?

I read David Morrison's article



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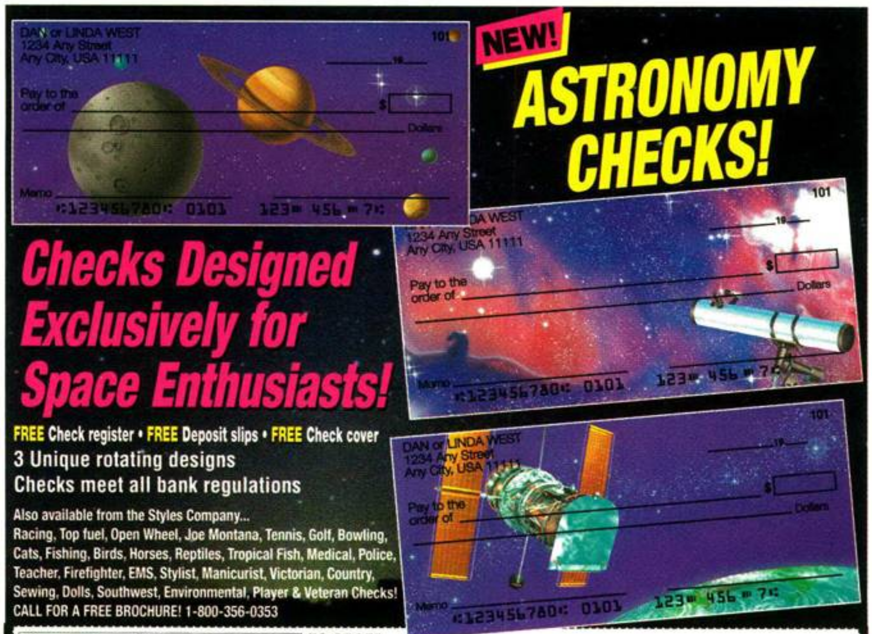

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LETTERS

"Target: Earth" (October 1995) with great interest and some skepticism. The past year has seen a veritable rash of nonfictional speculation on this subject, much of it expressed in shrill, apocalyptic terms.

Granted, the possibility of Earth being hit by a "regional bludgeon" in the next 500 years is not zero. But other civilization-threatening scenarios seem to have higher probabilities. Even after the collapse of the Soviet Union, numerous nuclear warheads remain in unstable hands. What about catastrophic volcanic explosions? Such an event could occur. On a more prosaic note, we may destroy so much of our collective forest that the remainder won't be able to produce enough oxygen to support life. We may pollute the atmosphere so badly that breathing will become difficult.

So far as I know, all of the near-Earth objects discovered thus far cross Earth's orbit the way the Verrazano Bridge crosses the Narrows. Thus, the probability that one of them will hit Earth is the same as the probability that a car crossing the Verrazano Bridge will hit a boat passing through the Narrows. — *Hugh Thompson, Flushing, New York*

L's Other Winners

I was glad to see the coverage of the National Outstanding Young Astronomer Award, presented last July at the Astronomical League meeting in San Antonio, Texas (November 1995). How about mentioning the three young astronomers who tied for second? They are Michael Deming of Mauriceville, Texas, Leia C. Scofield of Panama City, Florida, and Matthew W. Younce of St. Simons Island, Georgia. — *Matthew W. Younce, St. Simons Island, Georgia*

Correction

At the conclusion of "Mystery in Gemini" (October 1995), the newsletter *The Practical Observer* was misidentified as being published by the National Deep Sky Observers Society. The official NDSOS publication is *Betelgeuse*. For more information on the NDSOS, write *Alan Goldstein, 1607 Washington Blvd., Louisville, KY 40242.* ☐

ASTRONOMY welcomes feedback. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187, or on the Internet use letters@astronomy.com. Letters may be edited for length and clarity.

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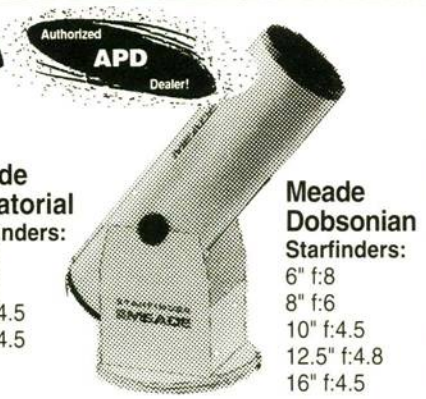

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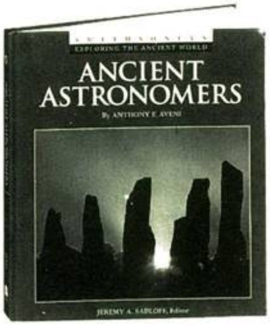
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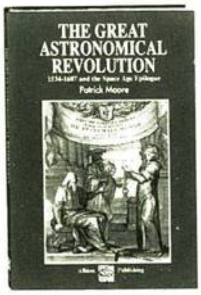
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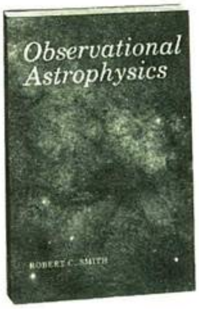
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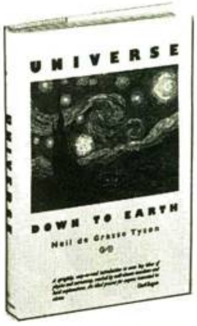
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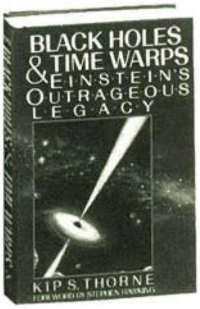
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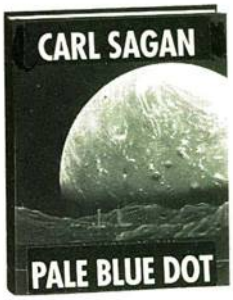
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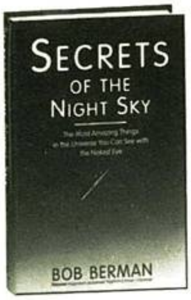
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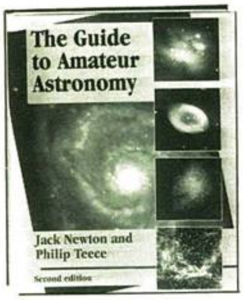
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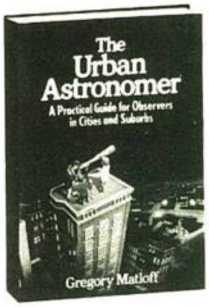
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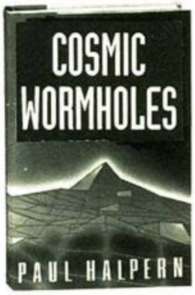
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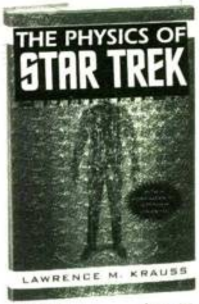
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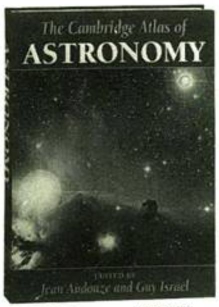
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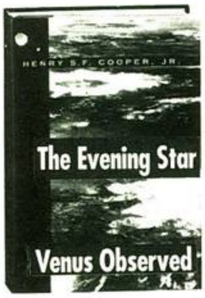
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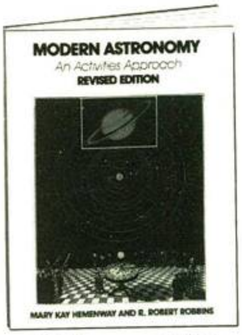
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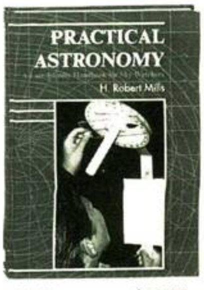
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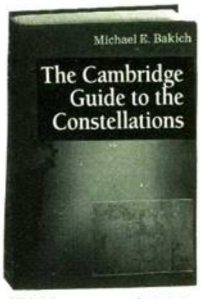
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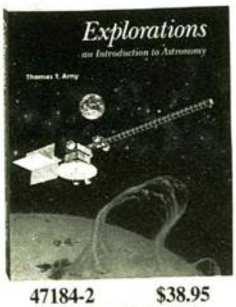
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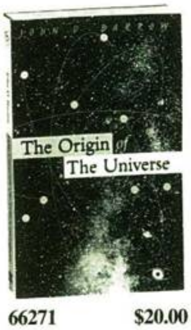
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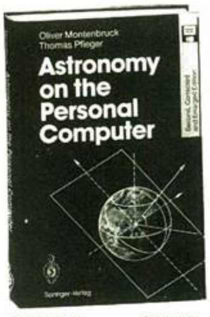
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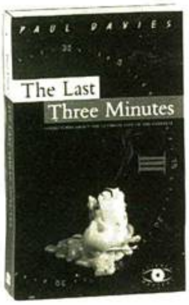
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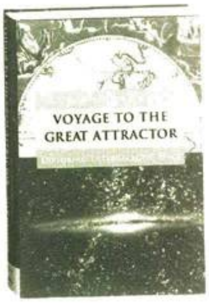
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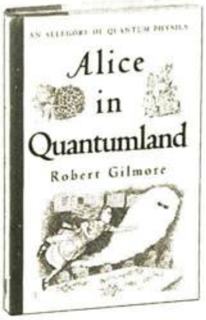
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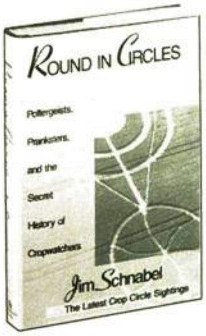
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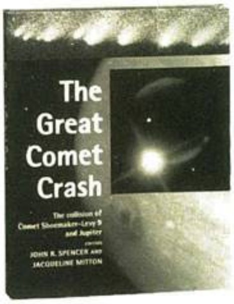
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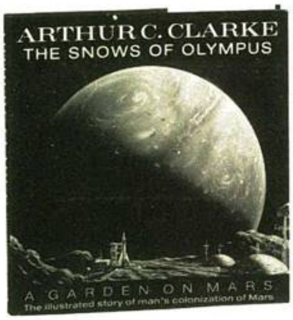
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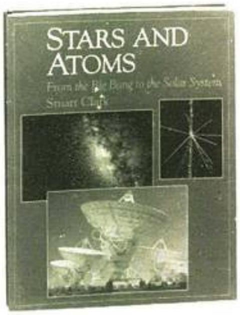
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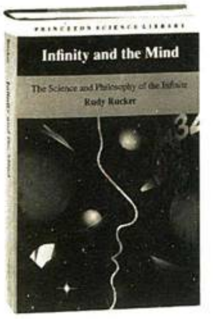
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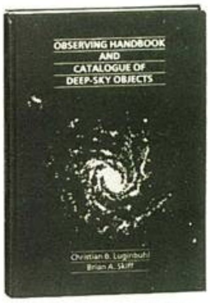
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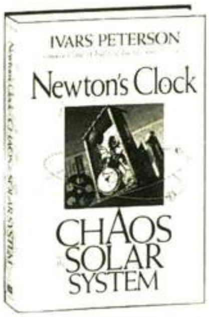
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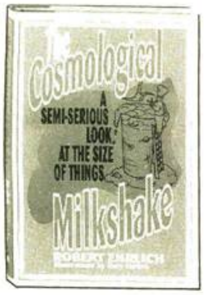
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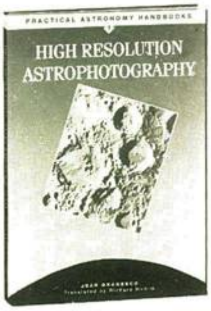
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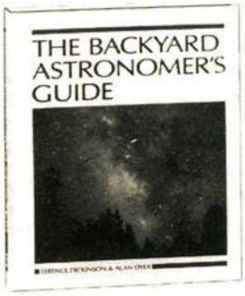
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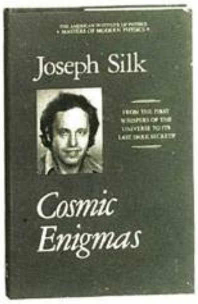
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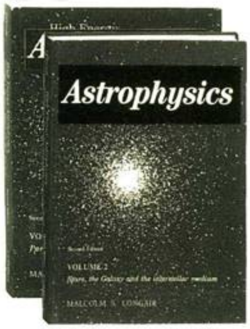
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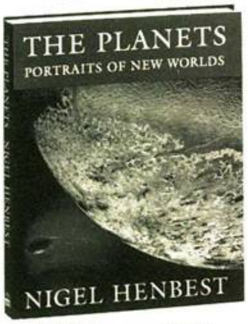
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ASTRO FORUM

The Relativity of Heaven

by Jeff Kanipe

Never let it be said that church isn't good for you. Thirty years ago I was just another 12-year-old sinner sitting in a south Texas Baptist church on a hot Sunday morning, sketching tic-tac-toes and rocketships in the margins of the four-page program notes with one of those stubby, eraserless pencils. I didn't know it then, but something was about to happen that would forever sway my thinking about the concept of Heaven.

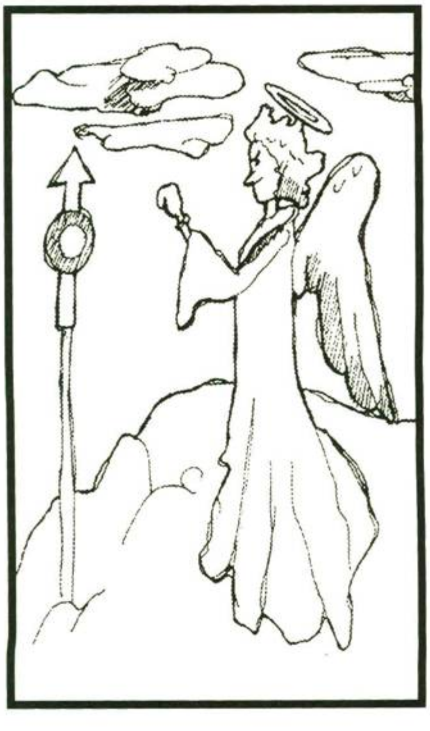
From the pulpit, the preacher — his white shirt damp with sweat, bald head shiny as a billiard ball, neck tendons stretched to the max — was doing his dead-level best to convince the congregation that we were all blithely skipping and prancing our way into Hell. Specifically, he was talking about what happens after death — one of his favorite subjects — how all sinners die, but that those who believe in the Jesus live forever. I was just thinking about folding the program into a paper airplane when suddenly the preacher's words went from the back of my mind to the front. He was saying something about infinity.

"Infinity," he intoned, making the word nearly six syllables long. "What does it mean? The scientist will tell you that it is a state where all equations fail. The scientist will tell you the laws of physics don't apply to the infinite. The scientist will dismiss infinity with a wave of his hand. But what the scientist will not tell you, your faith will, and your faith will tell you that infinity is eternity. It is endless time! A million years on Earth pass in the blink of the eye of one who beholds eternity. The only thing you need to decide, my friends, is where you want to spend eternity: Heaven or Hell?"

Naturally it made me uneasy to consider an eternal life in Hell. It didn't sound so good. But it didn't sound much better in Heaven, sort of slow and somber with a little too much white and gold paint. That could get old real quick. Still, something the preacher said resonated with a book I had just read called *Relativity for the Million* by mathematician and science writer Martin Gardner. It was a kind of everyman's guide to the essentials of Einstein's general and special theories of relativity, written in a style that was breezy, not a little tongue-in-cheek, and easy on the jargon. Gardner never mentioned "tensor calculus," but dealt head-on with the aesthetics of relativity, the right-brain side of Einstein's theories.

Gardner opened the book invoking a relativistic analogy, first proposed by the nineteenth century French mathematician Jules Henri Poincaré that, in light of what the preacher had just said, suddenly became absolutely vivid to me. Suppose, Poincaré said, that if overnight, while we slept, everything in the universe — everything — grew in proportionate size, say, a thousand times? When you awoke in the morning, could you tell such a transformation had occurred? The answer is no, unless something in the previous physical frame of reference had somehow kept the same proportions and now looked distinctly diminished and out of place — the state of Texas, for example.

Can we apply a similar analogy to time? Yes, because, like space, time is relative. Imagine that overnight while we slept, time abruptly accelerated at all scales so that years in the old time frame now equaled minutes in the new



one. In other words, every minute we experienced in the new time frame would be equivalent to a year in the old time frame. Would we be able to tell the difference?

Again the answer is no, unless we could view an object moving in the previous time frame — the planet Mars, say. With years of motion compressed to minutes, we would see Mars streaking across the night sky like a meteor. We would probably conclude that something was terribly wrong with Mars, though, not the universe! Technicians at the International Bureau of Weights and Measures would still measure the duration of 9,192,631,770 cycles of radiation corresponding to the transition between two levels of the ground state of the cesium-133 atom and call it a second. But besides Mars' motion, nothing in the universe would appear amiss.

Applying this kind of reasoning to the preacher's definition of eternity, if a million terrestrial years pass in the blink of an eye, then life on Earth must be flashing by to those already residing in Heaven (that's assuming its residents can, or would want to, observe us in our Earthly frame of reference). Whole mountain ranges would be raised in the time it would take an angel to flap her wings once in Heaven. The entire Roman civilization would rise and fall in a single sneeze from Hell. From Heaven's grandstand, the universe would effervesce: galaxies would wheel wildly across space and supernovae flash and off like fireflies in the dark forest of the cosmos. If such a view were possible from anywhere in the universe, I'd certainly call that place Heaven.

Admittedly, such a time shift in this universe is farfetched. Nevertheless, the laws of physics allow for space-time discontinuities in regions of dense, high-gravity objects such as black holes. At the heart of every black hole lies the incomprehensible "singularity," a point where matter becomes compressed to infinite density. Because the laws of physics break down at this point, we cannot learn anything about what's happening inside the singularity, which is to say that reality, as we know it, ends there. If you fell into the maw of a black hole, you would become subject to the same infinite conditions as your surroundings, except that "the laws of physics don't apply to the infinite." Neither would they apply to you.

Although time for you would appear to be ticking by normally, someone observing your descent from a safe distance would see the second hand on your wristwatch moving slower and slower as you approached the black hole's event horizon — the boundary where the escape velocity equals the speed of light. When you reached the event horizon, the observer would see the second hand on your watch stop, and you would appear frozen forever in black-hole limbo.

You, on the other hand, would notice nothing unusual in your frame of reference. Time would tick by normally. If you were able to look outside your frame of reference, however, you would see events in the universe unfolding faster and faster before your eyes. You would witness the entire future of the universe just as you entered the black hole and passed out of existence.

Now I'm not going to ask you to believe for a moment that Heaven, like the singularity of a black hole, must have an infinite density, but you must admit it's fun to think about the implications. For example, if Heaven truly exists, and if time is meaningless there, then as I see it we're all getting to Heaven at about the same time.

By now, you may be thinking that I need to get out of the house more often. That may be true. But consider this: Civilization has been around for five or six thousand years. That's not even a twitch in the eye of one who beholds the infinite. Thus, for all intents and purposes, everyone we know of in the history of the world, and everyone for a million years henceforth, have lived (or will live) and died (or will die) within a single beat of Local Heaven Time (LHT). That means all of us should arrive in Paradise nearly simultaneously. Nobody's late getting to Heaven!

Although I don't suspect it will happen in my lifetime, it wouldn't surprise me if science one day catches a tantalizing glimpse of the far side of infinity. They've come pretty close already. In the 1960s, it was laughable to think that science could describe the conditions during the first three minutes after the big bang. Now they can do it to within a trillionth-trillionth-trillionth of a second. I'm sure that whoever follows me into the afterlife will be only too willing to relay what has been learned about the infinite universe during my earthly absence. But by then, of course, we'll all know. ☐

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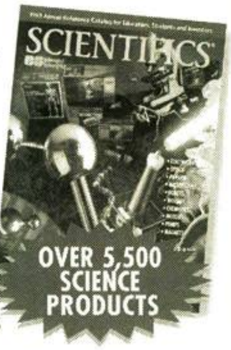

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ASTRO NEWS

The Best Brown Dwarf Yet

Astronomers have found an almost-surefire brown dwarf, a candidate that is so good that it's almost impossible to imagine what else it could be. If confirmed, it will prove the existence of these transitional objects that are too massive to be considered planets, but aren't massive enough to ignite nuclear fusion in their cores and thus shine like stars (see "Another Brown Dwarf?" AstroNews, January 1996).

Caltech astronomers led by Shrinivas Kulkarni discovered the probable brown dwarf orbiting Gliese 229, a red dwarf star 20 light-years away. The brown dwarf lies about 44 astronomical units from Gliese 229, putting it a little farther from the star than Pluto is from the Sun.

Based on the object's intrinsic luminosity, about 1/500,000 that of the Sun's, the temperature is less than 1000 kelvins. This perfectly fits the brown dwarf model: It is warmer than Jupiter but cooler than the coolest star.

The clincher, however, is the presence of methane in its spectrum. A star's tremendous heat will quickly break apart methane molecules, so the existence of methane means the object is too cool to be a star. "It's the most beautiful proof that it's a brown dwarf," says Geoff Marcy of San Francisco State University. "It smells like a brown dwarf and looks like a brown dwarf — you can almost taste the methane."

Kulkarni's team hasn't determined the object's mass yet. Gliese 229 appears to be about 5 billion years old. According to theoretical models, a 5 billion year-old brown dwarf with the luminosity of Gliese 229's companion should be about 50 times the mass of Jupiter. This is well below the 80 Jupiter-mass upper limit for brown dwarfs — anything heavier than that would shine like a star.

New Planet Update

The existence of a planet orbiting the solar-type star 51 Pegasi seems more certain (see "First Planet Found Orbiting a Solar Twin," AstroNews, January 1996). A second group of astronomers has confirmed the gravitational perturbations on 51 Pegasi that led to the original discovery by Michel Mayor and Didier Queloz of the Geneva Observatory. Other possible explanations for these perturbations on 51 Pegasi have been virtually ruled out. "The odds are wildly in our favor that the orbiting object has a mass of less than five Jupiters," says San Francisco State University astronomer Geoff Marcy. There are reports that the star might have a second companion object, although astronomers don't know yet if that object is a star or another planet.

Recent distance measurements by William van Altena and John Lee of Yale University indicate that 51 Pegasi is farther away than first reported: It is between 55 and 60 light-years away rather than 40 to 45. The star appears to be a G3 star nearing the end of its hydrogen-burning life cycle.

Studies by Adam Burrows at the University of Arizona indicate that the orbit is very stable, meaning the planet may have been orbiting the star for billions of years. More details will appear in next month's ASTRONOMY.

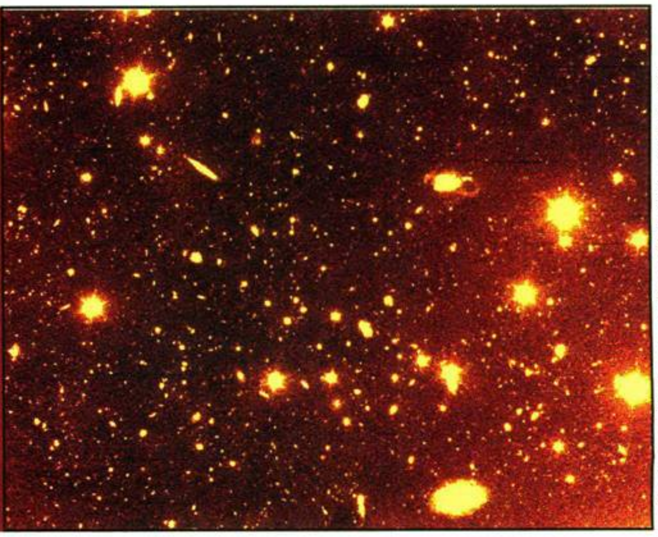
Black Holes Galore

It's getting harder to disbelieve the existence of black holes. Two teams, one from the University of California at Berkeley and one from Oxford University and the University of Southampton in England, have independently bagged yet another black hole candidate, one they consider to be the second best in the Milky Way Galaxy. "It's darn near certain," says Alex Filippenko of the Berkeley group.

The suspected black hole belongs to the binary system QZ Vulpeculae, located 14,000 light-years away. The black hole's companion is a cool dwarf star. Since 1988 astronomers suspected the system might harbor a black hole. That year the Japanese Ginga satellite observed the system as it became an X-ray nova. The flare up presumably was caused by material from the star falling onto the black hole, causing it to discharge huge amounts of X rays.

To confirm the black hole, Filippenko and his group observed the system with the 10-meter Keck Telescope in Hawaii. The

THREE HUNDRED BILLION GALAXIES? Deep images of distant galaxies made recently with the Keck Telescope in Hawaii suggest the observable universe may hold at least 300 billion luminous galaxies. A group of astronomers led by Ian Smail of the Carnegie Institution in Washington, D.C., imaged several fields down to magnitude 27 and extrapolated the results over the whole sky. The field shown here, itself containing 6,000 galaxies, is that of a faint galaxy cluster in Hercules.



Ian Smail, David W. Hogg, *et al.*/Carnegie Institution and Caltech

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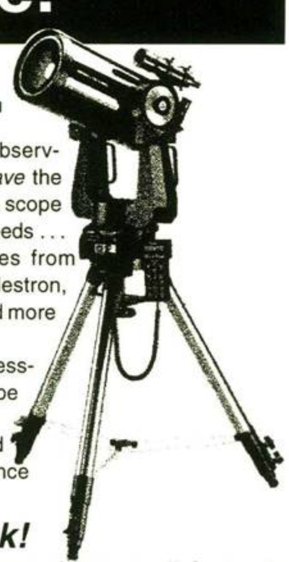

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astronomers were able to measure the precise radial velocity (520 km/second) and orbital period (8 hours) of the star as it orbits an invisible companion. From this data, they calculated that the companion has a mass of at least five Suns, probably six to seven Suns, and perhaps as many as 14.

According to most astronomers, the upper mass limit for neutron stars is about 3.2 Suns. If this is true, it's hard to imagine what else this object could be other than a black hole.

The English group, led by Jorge Casares, used the 4.2-meter William Herschel Telescope in the Canary Islands. They obtained virtually identical results.

Of the seven good black hole candidates in the Galaxy, the most convincing is V404 Cygni, whose mass is at least 6.1 Suns. The most widely known candidate, Cygnus X-1, probably has a mass between seven and 16 Suns, but it could conceivably be lower than 3.2 Suns.

The Many Faces of a Quasar

Quasar 1608+656 sits in Draco screaming out its presence from across 7 billion light-years of space to whoever will listen at the right radio frequency. That in itself is not unusual for quasars, which are thought to be the centers of active galaxies that formed shortly after the universe came into existence.

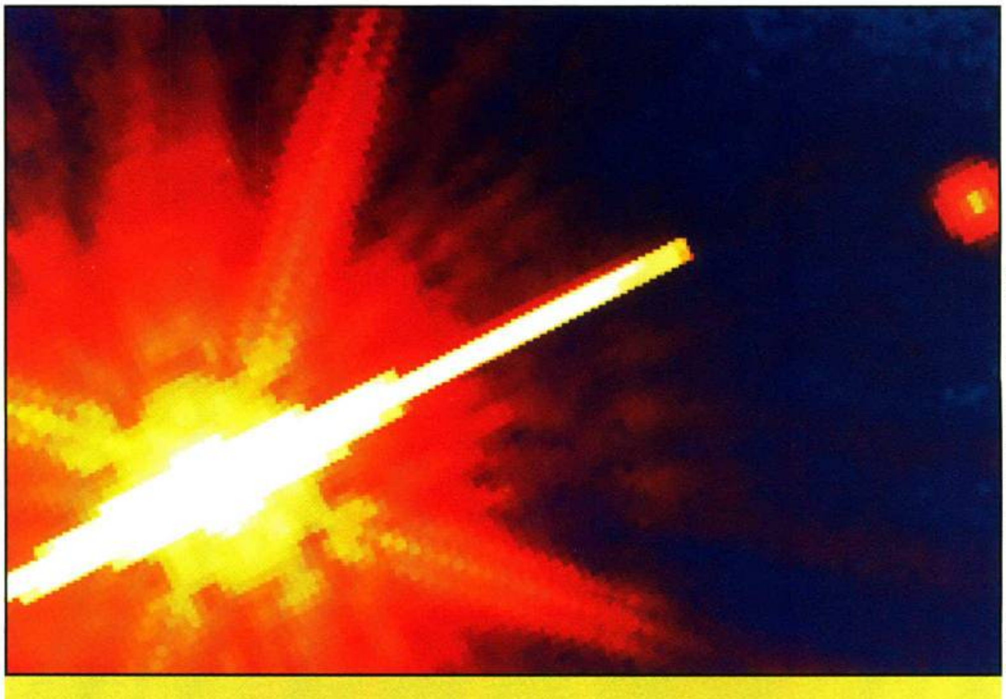
What makes 1608+656 different from many other quasars, though, is a 19th-magnitude foreground galaxy whose gravity is acting like a lens to distort our view of the more-distant quasar. The interloper splits the quasar's radio signal into at least four, and possibly five, distinct radio images. Two teams using the Very Large Array radio telescope in New Mexico independently discovered the quadruple lens system last year, and reported their findings in the July 1, 1995, issue of *Astrophysical Journal.*

As if discovering this circumstance weren't enough, both teams suggest that the gravity lensing of 1608+656 offers an opportunity to settle (or maybe fuel) a cosmological debate. Using a variety of methods, astronomers have calculated a range of values for the Hubble constant that suggests the universe is anywhere between 10 and 20 billion years old. By measuring time delays between each lensed image as 1608+656 varies ever-so-slightly in radio brightness, astron-

Nick James

A Nova in Cassiopeia

Nova Cassiopeiae 1995 peaked at magnitude 8.8 during the final days of August 1995. The object (epoch 2000 coordinates: 1h05.1m, 54°1') was discovered on films made by Minoru Yamamoto in Okazaki, Aichi, Japan, on August 24. Nova Cas 1995 was a classical nova, a double star system consisting of a normal star and a white dwarf. Material streaming onto the surface of the white dwarf reached a critical point and suddenly exploded.



David Golimowski (Johns Hopkins University) and NASA

ONE OF THE SMALLEST STARS KNOWN, Gliese 105C appears at the upper right of this Hubble image taken in near-infrared light. Located some 27 light-years from Earth in the constellation Cetus, Gliese 105C orbits the much brighter K-type dwarf star Gliese 105A seen at lower left.

A team of astronomers led by David Golimowski of Johns Hopkins University imaged the faint star which, if it were at the distance of the Sun, would appear only four times brighter than the Full Moon. Golimowski estimates that Gliese 105C contains 8 to 9 percent the mass of the Sun, just enough to burn hydrogen in its core.

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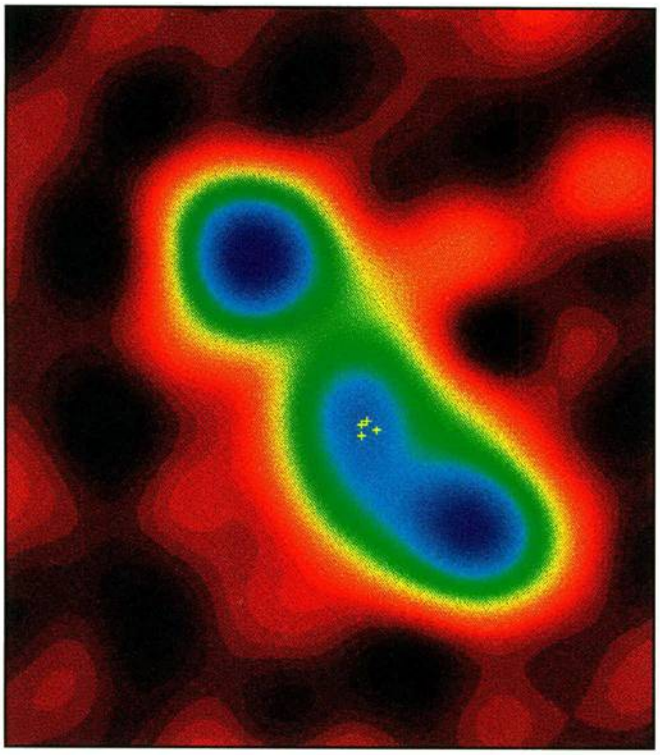


I. A. G. Snellen, Leiden Observatory

BLAZING FORTH IN RADIO TECHNICOLOR, quasar 1608+656's twin lobes span a third of the Moon's apparent diameter. The gravity of a galaxy along our line of sight has split the quasar's center into four nearly identical images, marked here by four tiny crosses.

omers should be able to calculate another value for the Hubble constant. In this way, 1608+656 might help determine the age of the universe.

But all this depends on settling two outstanding issues: picking up the quasar's tiny radio fluctuations and deducing the true nature of the lensing galaxy. Future radio studies at greater fidelity should pick up the subtle variations, while pictures taken by the Hubble Space Telescope ought to reveal the interloper galaxy's actual shape and mass distribution.

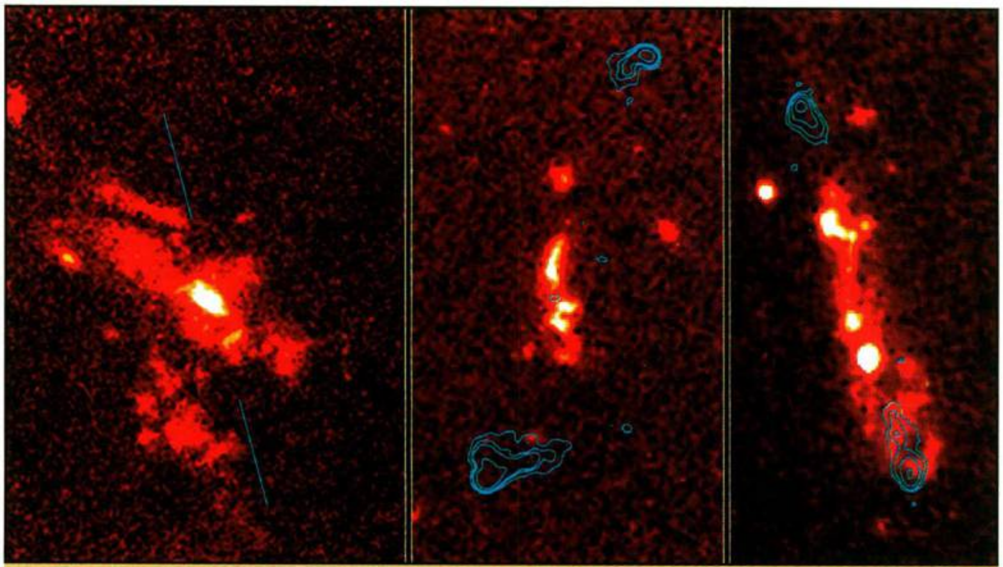
The Big Crunch

For decades, astronomers have been trying to put an end to the expanding universe debate. Some think the universe will continue to swell forever, while others believe that gravity will slow things down, recollapsing it in a "Big Crunch."

Putting an end to the debate hasn't been easy because measuring gravity's effect on the universe has been difficult — until now. Barbara Ryden of Ohio State University in Columbus recently devised a new way of using celestial maps that avoids inaccuracies have plaguing other methods.

Ryden's method looks at distortions in celestial maps that exist because astronomers plot the positions of galaxies according to their redshift. Redshifts measure how much a galaxy's light shifts toward the red end of the specturm as the galaxy moves away from Earth. Nearby galaxies have redshifts linearly proportional to their distance from Earth. For instance, if a galaxy 125 million light-years away has a redshift of 1%, then one 250 million light-years away would have a redshift of 2%, and so on.

But galaxies very far away from Earth, and likewise very far back in time, cannot be accurately plotted. Because the universe was much smaller and expanding faster in the past than it is today, distance is no longer linearly proportional to redshift at large distances from Earth. As a result, redshift maps tend to distort the view of the universe in much the same way



Malcolm Longair, Cambridge University, NASA, and NRAO

COMPLEX LOBES OF ENERGY characterize distant radio galaxies. The underlying images were made with Hubble; blue isophotes show radio emission observed with the Very Large Array Radio Interferometer.

The combination suggests the mechanisms that power radio galaxies are more complex than previously imagined. The energy may result from massive star-forming regions, dwarf satellite galaxies, and bow shocks caused by jets of gas shooting outward from the galaxies' centers.

The galaxies pictured are (left to right) 3C 265, 3C 324, and 3C 368. The blue lines in the 3C 265 image indicate its axis of radio emission, which is very different from the galaxy's optical axis. The bright clumps in each image may be super star clusters, satellite galaxies, or shocked regions of interacting gas.

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The **C4.5** uses the Polaris mount which is a very rigid German equatorial type. The very rigid wood tripod is fixed in height for added stability and is supplied with an accessory tray. A quote from *Astronomy Magazine*, "the **C4.5** stands out from the pack by having by far the best mount. Its Polaris mount is wonderful. Solid. Smooth. And with a damping time of two seconds. It was a joy using this telescope." "This is a first-rate telescope that outclasses the competition in the popular 4½" class of Newtonians." Further they said, "the C4.5 star images were classic textbook Airy disks".

Standard accessories include a 26mm multi-coated Plössl Eyepiece – 1¼" (35x), high quality 6x30 Finderscope and a 1¼" Focuser.

Firstscope 114 Its 910mm focal length (f/8) optical system is housed in an aluminum tube. This high quality yet economical telescope is made in a modern, high quality telescope factory in China to **Celestron's** specifications.

The equatorial mount is stable and includes setting circles in both axes as well as slow-motion cables in both axes for easy tracking. The wood tripod is adjustable in height and includes an accessory tray.

Standard accessories include a 5x24 Finderscope, 1¼" Focuser (with a .96" adapter), 20mm H–.96" Eyepiece (46x), 4mm SR–.96" Eyepiece (228x), 2x Barlow Lens –.96"

A **Firstscope 114 Deluxe** model is available which replaces all .96" accessories with two high quality 1¼" eyepieces – 25mm SMA (36x) and 10mm SMA (91x). The 1¼" accessories give you sharper views, a wider field of view and better eye relief.

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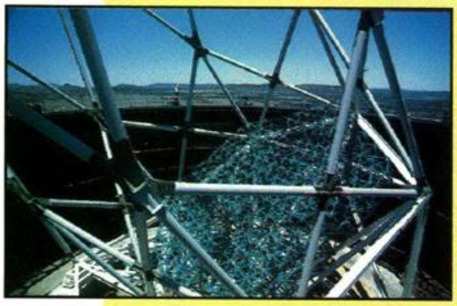
For more detailed information on these telescopes, contact a Celestron dealer or Celestron.

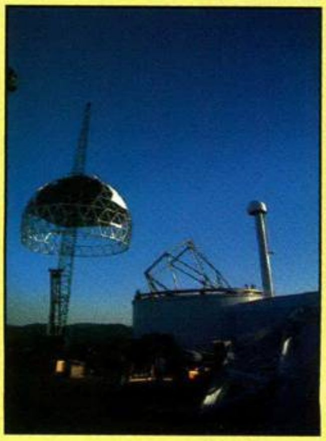
Celestron International • 2835 Columbia Street, Torrance, CA 90503 • (310) 328-9560 • FAX (310) 212-5835 a flat geographical map distorts the view of Earth.

Ryden hopes these distortions will provide clues to gravity's influence on expansion. When plotted, the distribution of galaxies has a distinct spongy pattern with big voids where no galaxies appear. The sizes and shapes of voids very far away and into the past hint at how rapidly the young universe was expanding. Small voids that are not very distorted suggest that gravity has not been significantly affecting the universe and it will continue to expand. Large and very distorted voids indicate a universe that was expanding much more rapidly in the past but now is being decelerated strongly by gravity. Such a universe will eventually recollapse in a Big Crunch.

Ryden's method combined with surveys of galaxies plotted out to larger and larger distances should provide cosmologists with more detailed information. One such effort, The Sloan Digital Sky Survey, will measure redshifts of about a million galaxies in three dimensions and out to distances of 2 billion light-years.

Nearing First Light





Almost completed, the Hobby-Eberly Telescope stands at the McDonald Observatory near Fort Davis, Texas. The telescope will focus entirely on taking spectra of objects and is a joint project of the University of Texas at Austin, the Pennsylvania State University, Stanford University, and two German universities, Ludwig-Maximilians-Universität in Munich and Georg-August-Universität in Göttingen. The picture taken last summer (bottom) shows the telescope already in place and the dome being installed. The telescope is fixed at an angle of 65°; a tracker beam (not yet installed) at the top of scope permits access to objects at declinations between –10° to +72°, or about 70 percent of the sky. The 11-meter mirror consists of 91 hexagonal segments held precisely in position by computer control on a complex mount (top). Plans call for the mirror segments to be installed this spring and first light through the optics in midsummer.

Larry Ramsey, Penn State Univ.

EVENT HORIZON

New Sunspot Cycle Begins

Sunspots may be making a comeback after a couple of years of spotty displays. Astronomers from Caltech announce that a lone sunspot observed from Big Bear Observatory in California last August at mid-solar latitudes marks the beginning of a new sunspot cycle and the end of a lull in solar activity. The new spot made its appearance at latitude 21°, which meets the criterion of a spot from the upcoming cycle. The peak in sunspot activity is expected to occur in 1998 or 1999.

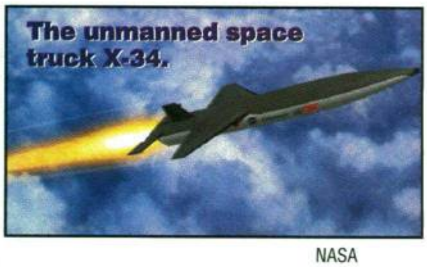
Gong!

And speaking of the Sun, all six stations of the Global Oscillation Network Group (GONG) are now up and running, making nonstop observations of wave motions in the atmosphere of the Sun. The continuous string of data will permit solar astronomers to determine the structure of the Sun's interior. The stations sit at Cerro Tololo Inter-American Observatory in Chile, Big Bear Solar Observatory in California, Learmonth Solar Observatory in Australia, Udaipur Solar Observatory in India, and Observatorio del Teide in the Canary Islands.

Mauna Kea's Newest Telescope

The 13,800-foot-high summit of Mauna Kea in Hawaii will soon sport another telescope. Construction workers broke ground in June for the Submillimeter Array being built by the Smithsonian Astrophysical Observatory. The array, which is expected to begin operation in late 1997 or early 1998, will consist of six movable antennas. When spread their widest, the antennas will act like a single 1,500-foot-wide telescope.

Winged Launcher Takes Shape



The unmanned space truck X-34.

NASA

NASA is taking its ideas of unmanned reusable payload launchers to new heights. The newest version proposed is the X-34, designed to lift lightweight payloads up to 2,500 pounds into low Earth orbit. The X-34 would be ferried via a modified L-1011 airliner to an altitude of 35,000 feet, where it would detach and fly to an altitude of 66 miles on its own rocket power. The X-34's payload would be launched from the payload bay. The 72-foot-long winged vehicle would then glide back to Earth and land on a conventional runway.

Lander Dummy Survives Crash Test

NASA's unique crash-bag landing system designed to ease the Mars Pathfinder lander to the Martian surface in July 1997 will work fine, even if the spacecraft alights on a rocky, inclined surface. Recently, engineers dropped a mock-up of the spacecraft from a height of 70 feet on to a platform of large rocks affixed to a 60° incline, to simulate the landing angle. The bag-enshrouded mock-up emerged unscathed.

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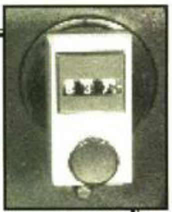

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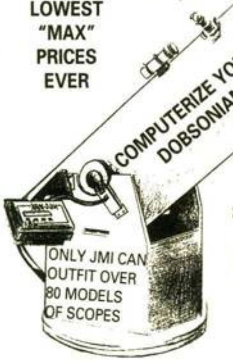
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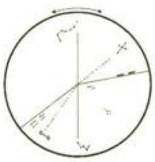

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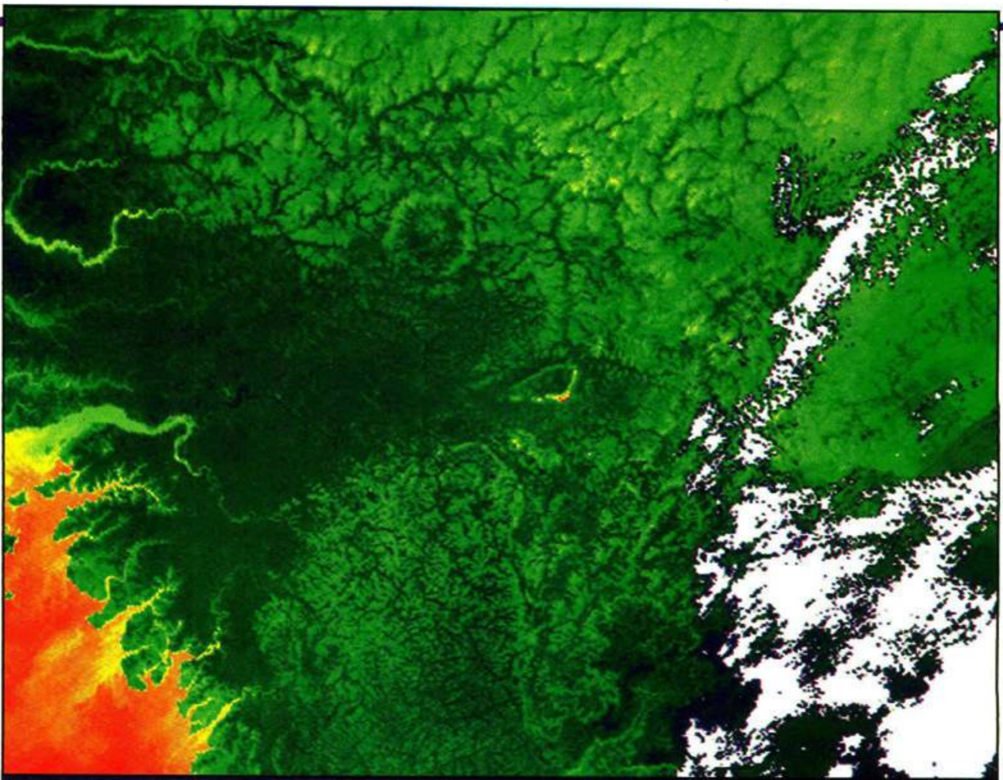
A Natural Laser in Space

Astronomers have discovered that lasers aren't confined to the realm of human technology. NASA's Kuiper Airborne Observatory, an infrared telescope mounted aboard a modified C-141 airplane, spotted the spectral signature of a powerful laser near a newly formed star in Cygnus.

A laser is an extremely focused beam of light restricted to a single wavelength. Lasers are created by a cascade effect. An atom in a high-energy state releases a photon. This photon strikes another atom in a high energy state, causing it to emit a photon at the same wavelength and in the same direction, which strikes another atom, and so on. In the case of the space laser, the newborn star's intense ultraviolet light pumps energy into hydrogen atoms in the surrounding disk, raising their energy level. When one of the hydrogen atoms spontaneously emits an infrared photon, it starts the chain reaction that produces an intense beam of infrared laser light.

In 1981 other astronomers spotted lasers in the atmosphere of Mars. But this new laser is millions of times more powerful. The astronomers who discovered the laser, led by Vladimir Strelnitski and Howard Smith of the National Air & Space Museum's Astrophysical Laboratory, believe it originates only 1 AU from the star. "It's providing us a probe very close to the star in a circumstellar disk," says team member Sean Colgan of the SETI Institute in Mountain View, California. "We might be able to see these around other stars and use them for similar purposes."



ESA

A NEW METEORITE CRATER? This image from the European ERS satellite shows a 40-kilometer-diameter ring in Africa (above center). Green landscapes include Senegal, Gambia, Guinea Bissau, and Guinea. The orange-red region at lower left is the Atlantic Ocean. The just-discovered ring is probably the scar from a meteorite impact. By studying the rocks at the site, geologists will be able to determine whether the ring is meteoritic in origin.

Sweeping the Outer Solar System

The billions of small comet nuclei that lie beyond Neptune in the Kuiper disk are not scattered uniformly in a multitude of random orbits. Instead, Neptune's gravitational influence shepherds them into elliptical orbits in a few narrow regions, reports Renu Malhotra of the Lunar and Planetary Institute in the July 1995 *Astronomical Journal*. If Malhotra is right, astronomers can use this information to find these faint objects more efficiently (see "First Drops in a Comet Reservoir," AstroNews, October 1995).

Malhotra analyzed how Kuiper disk objects evolved over time. She incorporated earlier research suggesting that Neptune formed closer to the Sun than its present location. According to this research, the young Neptune migrated outward because its gravity deflected more comets toward the Sun than away from it. The energy lost by these comets was gained by Neptune, causing its orbit tolowly expand.

As Neptune's orbit expanded, so did the planet's gravitational reach. Malhotra found that Neptune's gravity swept up Pluto and countless Kuiper disk objects into special orbital relationships called resonances. Pluto is in fact trapped in a 3-to-2 resonance with Neptune. This means that Neptune goes around the Sun exactly three times as Pluto goes around twice. Malhotra shows that if Neptune moved outward, the majority of Kuiper disk objects should be caught in either a 3-to-2 or 2-to-1 resonance with Neptune, with many more being snared in a 4-to-3 or 5-to-3 resonance.

The average distances from the Sun for objects caught in 3-to-2 and 2-to-1 resonances are 39.4 and 47.8 AU, respectively. But Malhotra's "resonance sweeping" mechanism also pumps up the eccentricity of these objects, so their distances from the Sun vary by 40 percent. "In real space you're not going to see bands in the sky," says Malhotra.

Still, an object caught in a 3-to-2 resonance like Pluto will always come to perihelion approximately 90 degrees away from Neptune's location. Because these objects are extremely faint, astronomers have their best hope of catching them at perihelion when they're at their brightest.

If Malhotra's model is correct, astronomers now know exactly where to look.

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Enchanted Skies

It was a perfect time and place for a conjunction. Alan Hale and Thomas Bopp, two names now linked to a comet that we'll be seeing a lot of soon, had no idea what the other guy looked like. Even two months after the comet's discovery they were still strangers who had never met each other.

So the organizers of the second annual Enchanted Skies Star Party (held in Socorro, New Mexico, September 21 to 24, 1995) arranged for Hale and Bopp to finally meet in person at the event. Which they did, to great applause and with a great deal of autographing of the official star party T-shirt, which read "I was there when Hale met Bopp."

The Enchanted Skies Star Party, hosted by New Mexico Tech and the National Radio Astronomy Observatory, was a fine success, with about 150 backyard astronomers from 40 states attending. Besides a rousing joint presentation about their comet by Hale and Bopp, the four-day star party also featured daytime talks by professional and amateur astronomers on topics such as "Galaxies Through Space and Time," "Exploring the Solar System With Radio Waves," and "The Fractal Universe."

At night, observing sessions were held at the Frank Etscorn Observatory on the New Mexico Tech campus. Intermittent clouds kept the viewing during the first two evenings to about an hour each. But many viewers caught a first telescopic glimpse of Comet Hale-Bopp while standing in the presence of one or both co-discoverers — which is not the sort of thing you can do at just any old star party.

Saturday night featured a special treat: a chuckwagon dinner on the ranch belonging to Smokey and Betty Pound. The Pound Ranch lies a dozen miles southwest of Socorro in the Chupadera Mountains. From the viewing site along a low ridge, no artificial lights interfered with the dark skies — although some lightning flashes lit up clouds in the distance.

G. B. Cornucopia, a ranger and archaeology interpreter at Chaco Canyon National Heritage Park, gave an inspiring talk on "A Thousand Years of Astronomy in New Mexico." Beginning as twilight fell, he painted a vivid picture of the Anasazi skywatchers of Chaco Canyon, whose descendants, he noted, probably live today in the pueblos along the Rio Grande.

As night deepened, the cool wind from the San Mateo Mountains slowed and the rattling dry grass grew still. When Cornucopia finished, the wind was silent and the Milky Way — the "spine of the sky" in Indian lore — arched overhead while countless stars glittered softly.

The 1996 Enchanted Skies star party is scheduled for October 10-13 — mark your calendar now.

SOUTHWESTERN VISTAS AND SOLITUDE marked the Pound Ranch during the Enchanted Skies Star Party in Socorro, N.M. last September. Many attendees got their first views of Comet Hale-Bopp during the event.

ASTRONOMY: Robert Burnham

'COMET HALE-BOPP' landed on Earth at the Enchanted Skies Star Party, in Socorro, N.M., last September. While Alan Hale autographs a T-shirt, Tom Bopp (red jacket) reminisces about the discovery.

Meet Me on Mt. Kobau

The stars above seemed to shine a bit brighter for 175 observing enthusiasts gathered at the 12th-annual Mt. Kobau Star Party, held August 23 through 27, 1995.

The party's 6,000-foot mountaintop venue in British Columbia is well known for providing both steady and transparent skies. Party organizers experimented with the event's format by eliminating talks in hopes of maximizing everyone's ability to stay up all night to observe. Indeed, five straight clear nights offered naked-eye observers a limiting magnitude no worse than 6.3.

The best observing came after a Saturday afternoon full of thundershowers. By 10 p.m., the freshly washed air sparkled from horizon to horizon with thousands of pinpoint stars while the Andromeda Galaxy spanned a glorious 4° to the naked eye. Observers easily cracked double stars separated by only 0.5" and eyed Saturn's razor sharp rings at over 500x. One breathtaking view was through Bryce Heartwell's 8-inch Maksutov-Newtonian aimed at the Sagittarius Star Cloud, which spans the width of five Full Moons. The same scope, fitted with two Barlows and working at 800x, split a double star only 0.3" wide and showed the Ring Nebula's central star.

Another highlight was exploring the emission nebula complex near Gamma (γ) Cygni with a special-purpose H-Beta filter. A field of view in the author's 18-inch overflowed with blobs and wisps of all shapes and sizes. Nebulosity was staggering in its richness and dwarfed even the Veil Nebula in enormity. Swapping in an Oxygen III filter showed only the brightest handful of Gamma Cygni nebulae in sharp contrast with the background.

This year's Mt. Kobau Star Party falls on the tail end of the Perseid meteor shower, between August 14 and 18. To get more information or register, write Kobau Star Party 1996, c/o Peter Kuzel, 4100 25th Avenue, Vernon, BC V1T 1P4 Canada. — *Alister Ling*

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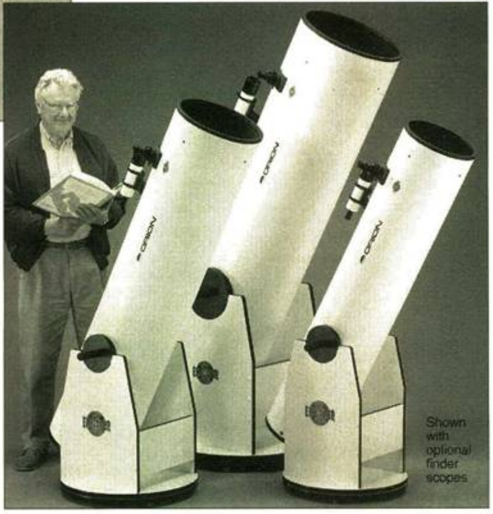

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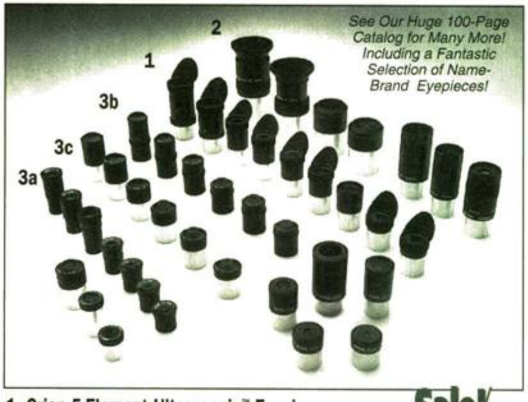

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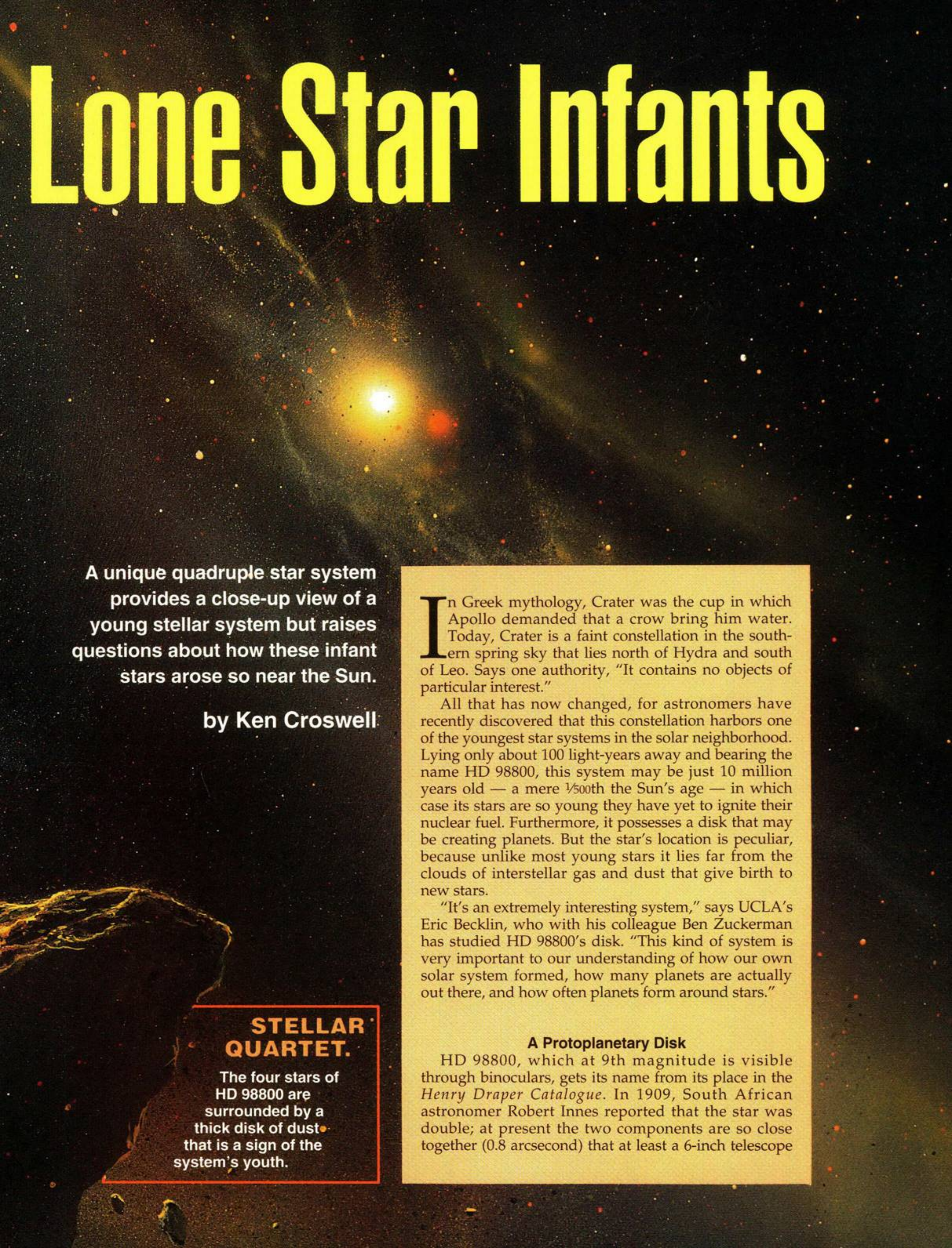
Lone Star Infants

A unique quadruple star system provides a close-up view of a young stellar system but raises questions about how these infant stars arose so near the Sun.

by Ken Croswell



STELLAR QUARTET. The four stars of HD 98800 are surrounded by a thick disk of dust that is a sign of the system's youth.

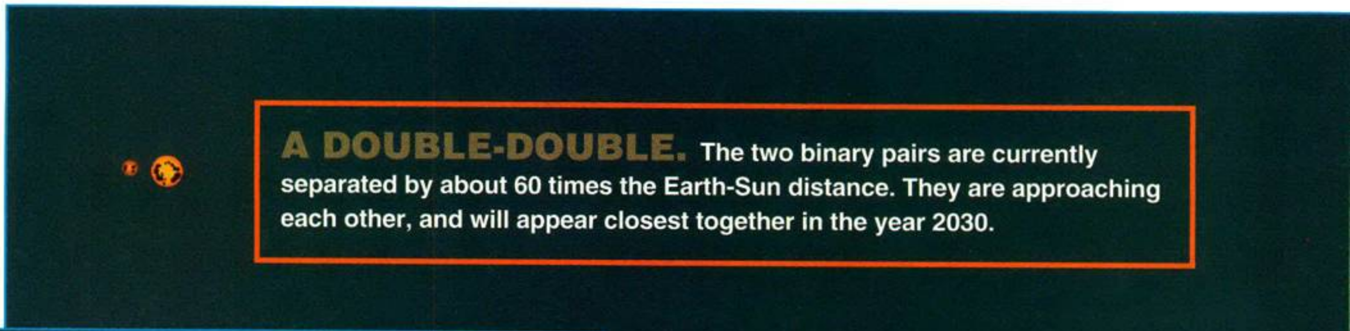
In Greek mythology, Crater was the cup in which Apollo demanded that a crow bring him water. Today, Crater is a faint constellation in the southern spring sky that lies north of Hydra and south of Leo. Says one authority, "It contains no objects of particular interest."

All that has now changed, for astronomers have recently discovered that this constellation harbors one of the youngest star systems in the solar neighborhood. Lying only about 100 light-years away and bearing the name HD 98800, this system may be just 10 million years old — a mere 1/500th the Sun's age — in which case its stars are so young they have yet to ignite their nuclear fuel. Furthermore, it possesses a disk that may be creating planets. But the star's location is peculiar, because unlike most young stars it lies far from the clouds of interstellar gas and dust that give birth to new stars.

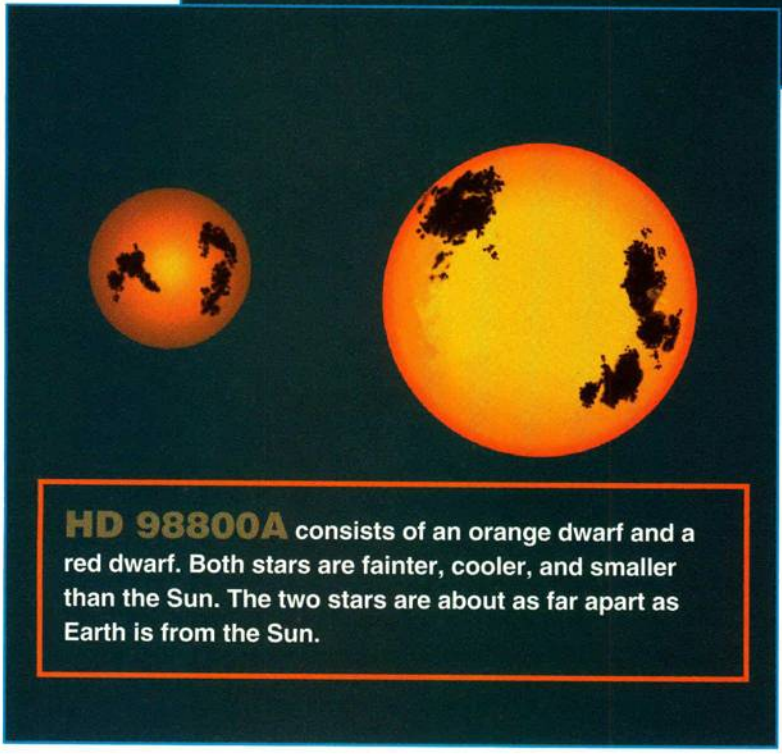
"It's an extremely interesting system," says UCLA's Eric Becklin, who with his colleague Ben Zuckerman has studied HD 98800's disk. "This kind of system is very important to our understanding of how our own solar system formed, how many planets are actually out there, and how often planets form around stars."

A Protoplanetary Disk

HD 98800, which at 9th magnitude is visible through binoculars, gets its name from its place in the *Henry Draper Catalogue*. In 1909, South African astronomer Robert Innes reported that the star was double; at present the two components are so close together (0.8 arcsecond) that at least a 6-inch telescope



A DOUBLE-DOUBLE. The two binary pairs are currently separated by about 60 times the Earth-Sun distance. They are approaching each other, and will appear closest together in the year 2030.

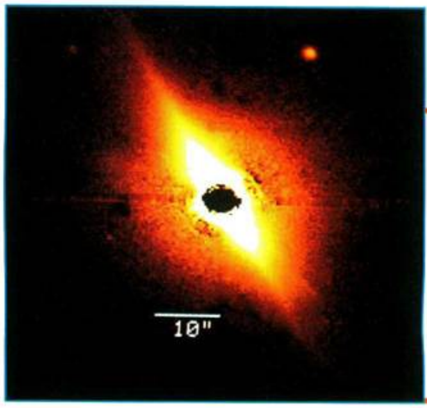


HD 98800A consists of an orange dwarf and a red dwarf. Both stars are fainter, cooler, and smaller than the Sun. The two stars are about as far apart as Earth is from the Sun.

ASTRONOMY: Thomas L. Hunt

under excellent seeing conditions is needed to split them. Both stars — HD 98800A and HD 98800B — are orange K-type stars that are somewhat fainter, cooler, and smaller than the Sun. Such objects are common, making up 15 percent of all stars, so no one thought much about the pair in Crater.

The first tip-off to the star's unusual nature came in 1988, when astronomers found that HD 98800 emits more infrared light than it should. Such an infrared excess had first been seen around the bright nearby A-type star Vega in 1983 by NASA's Infrared Astronomical Satellite (IRAS). The infrared excess signals the presence of orbiting dust. Vega's light heats the dust, which reradiates the light at infrared wavelengths. In 1984, astronomers found a more dramatic example when they actually photographed dust around another nearby A-type star, Beta Pictoris. The dust may be the remnant of a protoplanetary disk similar to the one that produced the Sun's planets 4.6 billion years ago.



BETA PICTORIS is a young star that is surrounded by a dusty disk, just like HD 98800. Planets may someday form from this disk.

Paul Kalas and David Jewitt/Univ. of Hawaii

But HD 98800 trounces both Vega and Beta Pictoris. As Zuckerman and Becklin pointed out in 1993, HD 98800's infrared excess is a whopping 10 percent of the star's total luminosity. For comparison, Vega's infrared excess is only 0.0023 percent of the star's total luminosity, and Beta Pictoris' excess is 0.25 percent.

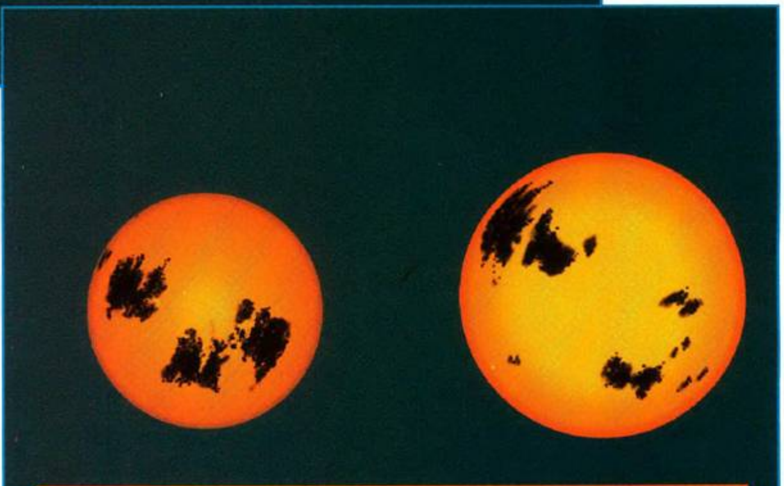
At first, though, Zuckerman and Becklin didn't believe HD 98800 was this extreme. "Because HD 98800 was so spectacular," says Becklin, "we suspected that the IRAS source was a background galaxy." But Zuckerman and Becklin's infrared observations confirmed that this seemingly ordinary star was indeed producing the infrared radiation. Despite their work, astronomers do not know exactly where the disk is — whether it is around HD 98800A, around HD 98800B, or whether each star has its own disk, in which case the system has two disks.

In their 1993 paper, Zuckerman and Becklin wrote: "In many ways, HD 98800 is the most unusual source in the IRAS catalogs. . . . So much [dust] is involved . . . that it is hard to imagine where it all came from, how it can remain in orbit around HD 98800, and why it does not collapse very quickly to a thin planar disk similar to Saturn's rings."

A Young, Active Star

Zuckerman and Becklin's work caught the attention of Bernard Bopp of the University of Toledo, who studies fast-spinning cool stars. "I read their paper, and little alarms went off," says Bopp. "The star is smaller than the Sun, cooler than the Sun, but considerably younger than the Sun. I know those stars real well — I've looked at them not in the context of protoplanetary disks but in the context of the activity that is analogous to sunspots and flares on the Sun."

Young K-type stars often spin fast. The rapid rotation amplifies the stars' magnetic fields, which create large starspots that cause the stars' brightnesses to vary. Like a lighthouse in reverse, the star dims whenever a large dark spot rotates past us. Bopp predicted that the stars of HD 98800 would vary in brightness. This prediction proved true. In 1994, Gregory Henry of Tennessee State University and Douglas Hall of Vanderbilt University reported that the brightness of the larger star, which gives off most of the light seen



HD 98800B consists of either two orange dwarfs or an orange dwarf and a red dwarf. The two stars are also separated by about the Earth-Sun distance. Young stars like these have large starspots.

from Earth, varies 7 percent every 14.7 days.

But Bopp's most important — and controversial — work concerned HD 98800's age. He and Francis Fekel of Tennessee State University put this at less than 10 million years, which means the star has not yet begun to ignite its hydrogen fuel and so is not a main-sequence star like the Sun. Instead, HD 98800 is a pre-main-sequence star, shining by converting gravitational energy into heat and light.

The key to this claim was the star's huge abundance of lithium, an element that is prominent in the spectra of young stars but gets destroyed by their nuclear burning as they age. "To find a lithium line of this strength was very unusual," says Bopp. Fekel and Bopp found that the star had ten times more lithium than similar stars in the nearby Pleiades cluster (410 light-years from Earth), which is itself quite young, with an age of only about 70 million years.

But David Soderblom of the Space Telescope Science Institute in Baltimore, who has recently studied HD 98800's lithium in more detail, is cautious about using the element to assign an exact age. "My best guess is that it's a pre-main-sequence object — 10 or 20 million years old," he says, "but you honest-to-God can't tell. You can go into the Pleiades and see a large range of lithium abundances. So there are processes that enable some stars to preserve their lithium when other stars that are right next door to them deplete it." Thus, despite its lithium, HD 98800 could be as old as the Pleiades.

The best way to tell the age is to measure the distance, which would reveal the stars' intrinsic brightnesses. Pre-main-sequence stars are more luminous than main-sequence stars of the same color. If HD 98800 turns out to be 100 or 150 light-years away, it is luminous enough to be a pre-main-sequence star; if it is 60 or 70 light-years away, then it is a less luminous, main-sequence star. Soderblom's team will use NASA's Hubble Space Telescope to measure the star's parallax and thus its distance, thereby establishing the age. He hopes to have the answer in 1997.

If HD 98800 turns out to be only 10 million years old, that will solve one puzzle — how the star could have so much dust — because such dust was left over from the star's formation. But Fekel and Bopp's work raised a more enduring mystery: Why does such a young star lie near the Sun?

Lone Stars

Young stars are normally found with hundreds of siblings in stellar nurseries, large clouds of gas and dust like the Orion Nebula. But HD 98800 does not lie in such a cloud. If its distance is 100 light-years, it is a long way from the nearest stellar nurseries, which lie 500 light-years from Earth.

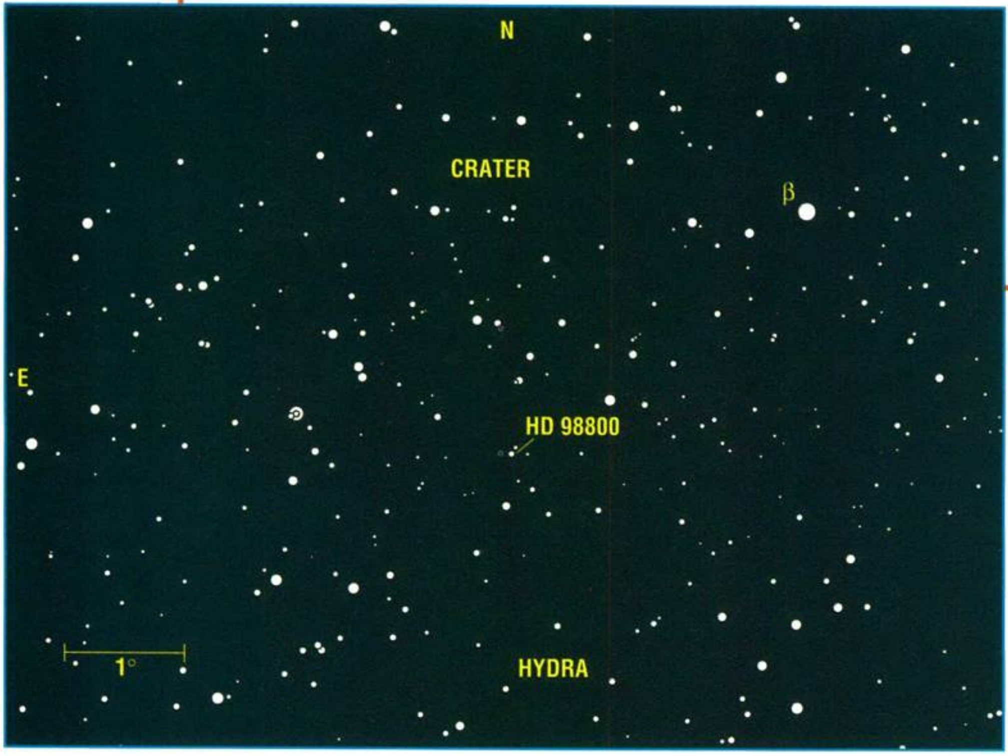
"There are very few stars in the solar neighborhood that are even as young as the Pleiades," says Soderblom. "They're older than that because it takes about that long for the stars to get spread around in the Galaxy. HD 98800 has gotten well-removed from its place of origin." In his view, HD 98800 formed in a large cloud of gas and dust but escaped, perhaps after passing too close to another star, whose gravity flung the system away. If its speed is typical, the star has traveled hundreds of light-years through the Galaxy in the last 10 million years.

Or perhaps the star formed where it is, in a tiny star-forming region. In 1992, Brazilian astronomers led by Jane Gregorio-Hetem noted that HD 98800 is 10 degrees from TW Hydrae, a T Tauri star. T Tauri stars are variable stars that are even younger than HD 98800, being about a million years old. The Brazilian astronomers proposed that a small cloud recently gave birth to a few stars in Crater and in the nearby constellations Hydra and Centaurus.

"I certainly think that star formation can take place in smaller clouds than the spectacular ones," says Bopp. "For every Orion Nebula, there's probably a number of other star-forming regions that are consid-

Track Down Runaway Star System HD 98800

The enigmatic star system HD 98800 not only challenges stellar dynamicists, but the backyard observer as well. It's nestled in southern Crater about 3° southeast of β Crateris, at R.A. 11h22m, Dec. –24°46.7'. As far as multiple stars go, HD 98800 is a tough target to split, requiring at least a 6-inch telescope working under steady seeing conditions. What makes the star so challenging is not its overall brightness — at around magnitude 9.5, it lies will within the light grasp of even the most moderate of backyard scopes — but the pair's tiny 0.8" separation and similarity in brightness. Use at least 300x to glimpse what might appear as an elongation in the star's image extending northeast to southwest.



erably smaller and less spectacular." Nevertheless, Bopp suspects HD 98800 has escaped from some larger star-forming complex.

To test whether HD 98800 is fleeing from a stellar nursery, astronomers are using data from the European satellite Hipparcos to measure the star's motion across the sky. Combined with the star's velocity along our line of sight — known from the Doppler shift — and the star's distance, this will allow astronomers to trace back where HD 98800 came from. The Hipparcos data will be released in late 1996 or 1997. Meanwhile, other astronomers were discovering additional complexities in this puzzling star.

Four Stars in One

Since 1989, astronomers at the Harvard-Smithsonian Center for Astrophysics led by Guillermo Torres have been observing blueshifts and redshifts in HD 98800's spectrum. These Doppler shifts indicate the stars' velocities toward or away from us. Torres' team found variations in the stars' velocities that revealed additional stars tugging on the main ones. But the system turned out to be so complex that the team published its work only in 1995.

Torres' team found that HD 98800 is not two stars but four. Each visible star is itself double. HD 98800A's companion is probably a red dwarf, whereas HD 98800B's companion is either an orange or a red dwarf. Each lesser star is about 1 AU from its brighter mate and takes less than a year to orbit it. One AU — astronomical unit — is Earth's distance from the Sun.

HD 98800A and B presently lie about 60 AU apart, twice Neptune's distance from the Sun. But the orbit is extremely elliptical: A and B are separated by thousands of AU at their farthest point. The orbit is so large that A and B take at least 100,000 years, and maybe millions of years, to revolve around each other. But by good luck, they will next be closest together in the year 2030, when they will be about 30 AU apart, so astronomers will be able to watch them interact.

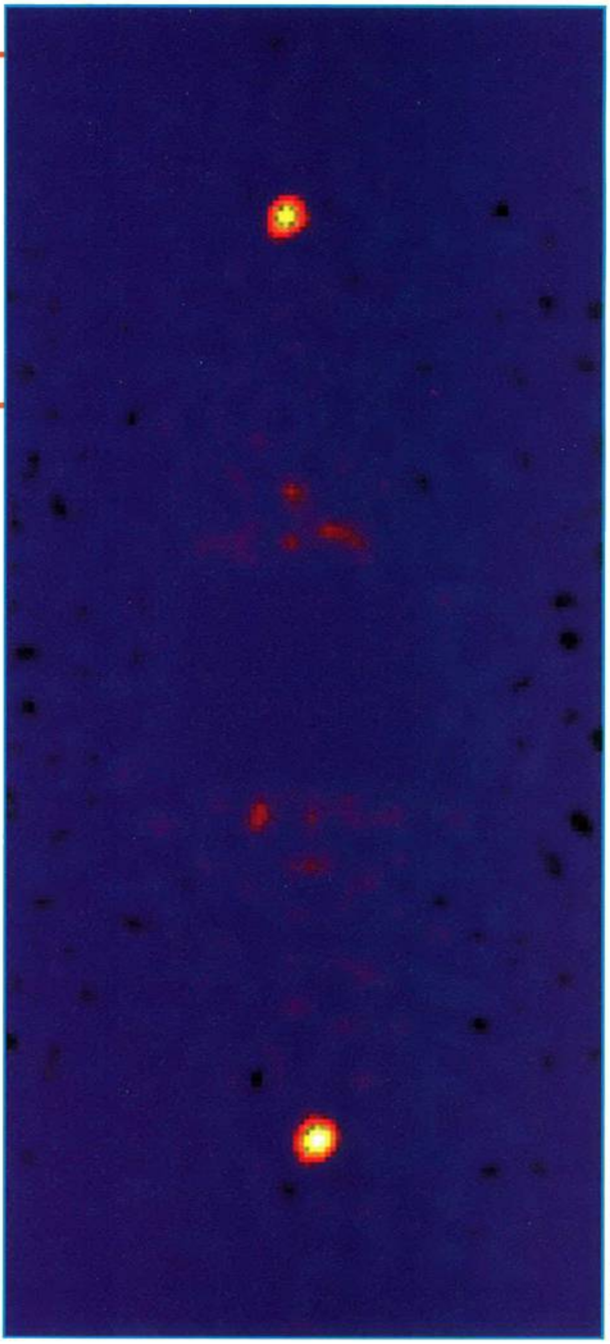
The upcoming close approach may actually explain why the infrared excess is so large. Perhaps one star's gravity is fluffing up the disk around the other, so that the disk blocks a larger percentage of starlight. This would explain why the disk is not as thin as Saturn's rings. And light from one star may heat dust around the other, adding to the infrared excess.

"We can't rule out that this is the first time the stars have approached each other," says Harvard-Smithsonian team member David Latham. "So the event coming up in 2030 may disrupt the dust that's producing

The Rogue Planets of HD 98800?

If HD 98800A and B are approaching each other for the first time, their planets may soon be cast into space. Imagine that you are a long-lived resident on such an unfortunate world, a planet lying as far from HD 98800A as Saturn does from the Sun. For millions of years, your planet has faithfully circled the two stars of HD 98800A, the brighter of which appears roughly a thousandth as bright as the Earth's Sun. For as long as you can remember, there has always been an intensely bright double star in your sky, sometimes visible by day, sometimes visible at night — HD 98800B. But lately, its brightness has grown and grown, almost rivaling that of your twin suns. In subsequent decades, you see this double star fade, but your suns have been fading as well, and you realize with horror that your planet has been cast into the depths of space, to be forever deprived of the little light and heat it received from the stars you call your suns.

the infrared excess.” Another possibility, he says, is that the stars have made several orbits, and that the disk(s) replenish themselves with dust when the stars are far apart. This happens because small bodies in the disks collide and produce dust, which then gets swept away when the other star passes by.



SPLITTING THE PAIR. Computer processing can easily resolve the system into two stars. No one as yet has been able to resolve all four stars.

CHARA/Georgia State Univ.

But this quadruple system leaves little room for planets. If the Sun had a companion star 1 AU away, as both HD 98800A and B do, then Mercury, Venus, Earth, Mars, and possibly Jupiter would have been ejected by its gravity; and if another star came within 30 AU of the Sun, as HD 98800A will to HD 98800B in 2030, then Saturn, Uranus, Neptune, and Pluto would have been ejected. In fact, if this is the first time that HD 98800A and B have approached each other, several of their planets may soon be cast into space. Other rogue planets, rudely cast out of their birthplace in a similar fashion, may already roam the Galaxy.

The Future Approaches

Over coming decades, astronomers will watch as HD 98800A and B perform their celestial pas de deux. The approach of one star should light up the other's disk of dust, boosting the infrared excess to even greater levels than exist today. Ultimately, though, this or future encounters may destroy the disk altogether, eliminating the infrared excess that first signaled the unusual nature of this system. In addition, astronomers will be paying close attention to the exact path the two stars follow in order to better determine their orbits.

“HD 98800 is still a unique object,” says Bopp. “But it shouldn't be. Certainly there should be other young stars like it that show infrared excesses and maybe protoplanetary disks as well.” Ironically, in 1995 astronomers led by Thierry Lanz of NASA's Goddard Space Flight Center reported that the “classic” dust-disk star — Beta Pictoris — may also be extremely young, with an age of only 12 million years. It had previously been pegged at over 100 million years old. Beta Pictoris lies just 53 light-years from Earth, even closer than HD 98800.

“We're always on the lookout for really young, nearby stars,” says Latham. “People used to say there just weren't any, but now there are two or three of them.” Young nearby stars are ideal targets for planet and brown dwarf hunts. Because they are young, any accompanying planets and brown dwarfs should still be warm and luminous; because they are nearby, they may be visible from Earth.

Of course, even a system as interesting as HD 98800 came to attention only recently. “There's an awful lot of nearby stars that nobody has ever gotten around to looking at in detail,” says Soderblom. “Compared with many things, HD 98800 is bright: It's 9th-magnitude. But there are a lot of 9th-magnitude stars that we know precious little about.”

Ten years ago, HD 98800 was one of those little-known stars, but it has since rocketed from obscurity to fame and revealed much about how young stars enter the Galaxy. Indeed, this star's history reminds us that even our own Sun might have been prematurely tossed out of its stellar cradle shortly after birth. As a member of a cluster of young stars, the Sun could have passed too close to a large star and been ejected by its gravity, perhaps before the Sun had a chance to ignite its nuclear fire. If so, the infant Sun would have watched its siblings recede into the distance as it confronted the depths of the Galaxy alone, accompanied by the soft glow of nine newborn planets. □

Ken Croswell is author of The Alchemy of the Heavens *(Doubleday/Anchor, 1995). The home page for the book is: http://www.ccnet.com/~galaxy/.*

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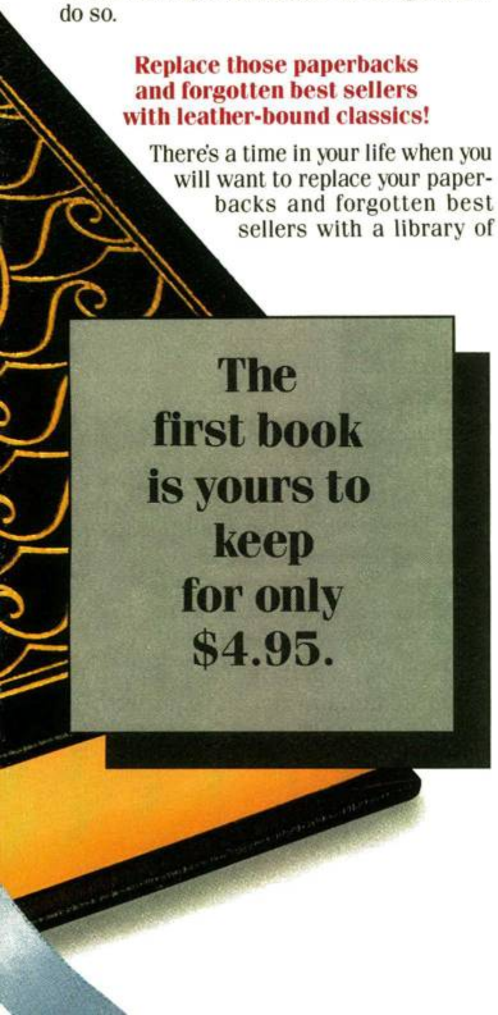

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STELLAR GRAVEYARD

Hubble Space Telescope has found dozens of burned-out stars that may settle debates about the age of the universe.

by David Bruning

Luke Dodd

Cosmologists say the universe may be only 8 billion years old. Stellar astronomers disagree. They contend the universe is much older, perhaps as much as 20 billion years.

Both answers derive from models of how the universe expands over time and how stars age, respectively. A key element in stellar astronomers' arguments is the age of the oldest stars, those in globular clusters. Hubble Space Telescope observations of burned-out stars in globulars may at last fix the ages of the oldest stars and, thus, the age of the universe. Astronomers took the first step recently when they uncovered several dozen white dwarfs, the burned-out remains of once bright stars, in the cluster M4 in Scorpius.

Globular clusters contain several hundred thousand stars. They presumably formed shortly after their parent galaxies did and thus shortly after the birth of the universe itself. Assuming that the cluster spawned all of its stars at the same time, researchers can determine the cluster's age by finding the age of its stars.

Unfortunately, most of the inhabitants in a cluster are main sequence or middle-aged stars, and like TV personality Dick Clark, do not show their age. Past estimates of the cluster's age depended upon finding red giants or other stars nearing the end of their life cycles. Astronomers then modeled how the stars age to reproduce the numbers, colors, and brightnesses of red giants and main sequence stars. The age of the star model that most closely represented the observed cluster colors and brightnesses provided the estimated age of the cluster. From this method M4 has an estimated age of 14 billion years.

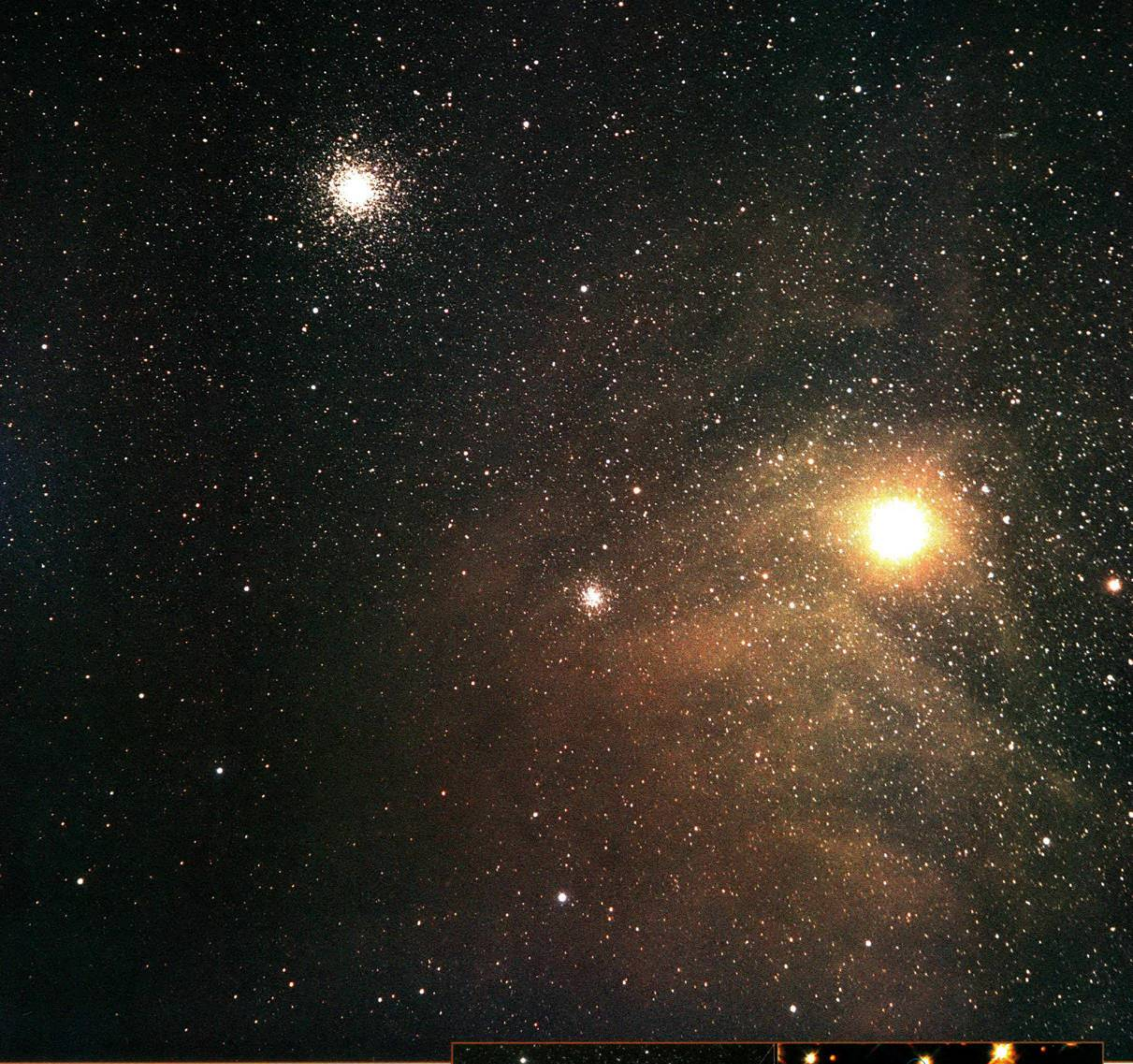
Scientists would rather have a direct determination of the age so they don't have to worry about whether their models truly represent how stars change over time. Stellar graveyards may provide the best results.

When a star like the Sun dies, it throws off its outer layers into space and leaves behind the hot glowing core — a white dwarf. The stellar remnant slowly radiates its energy into space, gradually cooling like the embers of a fire. Because it takes billions of years for the white dwarf to cool entirely to become a black dwarf, a globular cluster should contain thousands of faint, cooling white dwarfs. How quickly the stars cool depends on their temperature and luminosity.

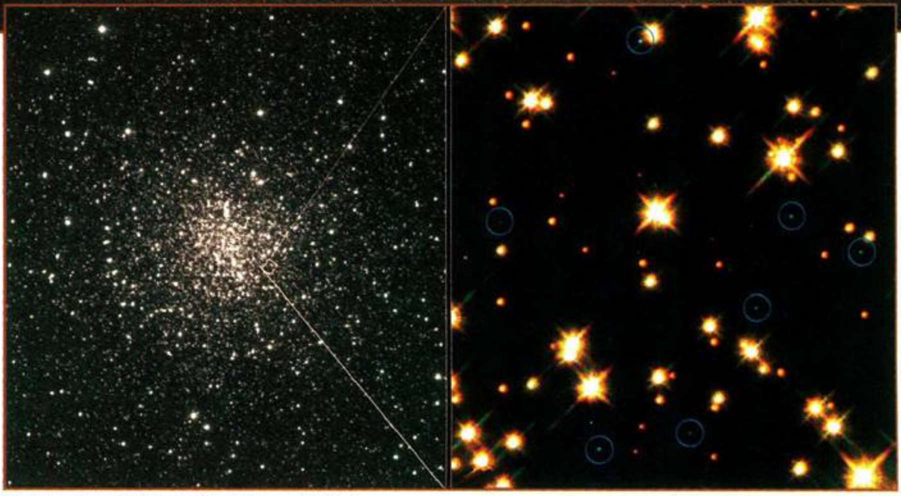
All white dwarf cores start out with a temperature of about 100 million kelvins. Knowing the present temperature and the rate of cooling tells astronomers how long ago the white dwarf formed. The oldest white dwarfs result from stars with short main-sequence lifetimes, so their cooling times are roughly equal to their ages and provide a lower limit to the age of the globular cluster.

Until recently, observers found only a handful of white dwarfs in various globular clusters, not enough to estimate the age of any cluster. But the sharp optics of the Hubble Space Telescope can peer into a cluster and separate the faint glow of white dwarfs from the bright light of main-sequence stars and red giants. Using the Wide Field and Planetary Camera 2, a team led by Harvey Richer of the University of British Columbia in Vancouver found more than 75 white dwarfs in M4.

The Hubble results will help set cooling rates for white dwarfs, an important first step in determining the age of the universe. Future longer exposures could find fainter, older white dwarfs that would enable astronomers to find the age of the cluster and settle the debate about the age of the universe. □



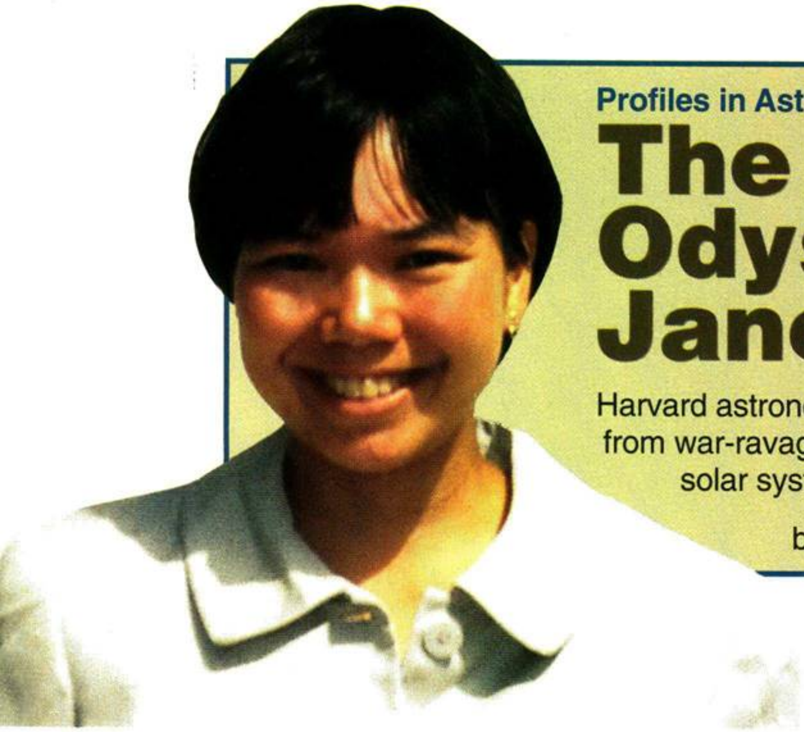
HUNDREDS OF THOUSANDS OF STARS CROWD the globular cluster M4, visible at top in the constellation Scorpius. The brightest star in Scorpius appears at right, the supergiant Antares (south is at top). A more distant globular, NGC 6144, lies near the center of the image. Accurate appraisals of cluster ages should settle current debates about the age of the universe.



BURNED-OUT STARS called white dwarfs became visible for the first time in large numbers when the Hubble Space Telescope searched small regions of M4 (the box at right is 0.63 light-year across). These stars are pivotal for cluster age determinations.

M. Bolte, Univ. of California, Santa Cruz, and NOAO

Harvey Richer, Univ. British Columbia, and NASA



Profiles in Astronomy:

The Remarkable Odyssey of Jane Luu

Harvard astronomer Jane Luu's life journey has taken her from war-ravaged Vietnam to the outer reaches of the solar system.

by Marcia Bartusiak

With space probes examining nearly every nook and cranny of the solar system, new finds in planetary astronomy are rare. But Jane Luu of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., beat the odds in a spectacular way. In 1992 she and her longtime collaborator, University of Hawaii astronomer David Jewitt, discovered a 280-kilometer-wide object orbiting the Sun beyond Neptune and Pluto. In the intervening years, they and others have spotted 27 more of these trans-Neptunian objects.

These newly discovered bodies belong to the "Kuiper belt," a disk of icy planetesimals that had long been proposed to exist beyond the outer planets. The Kuiper belt, or Kuiper disk as some astronomers call it, consists of leftover material that never accreted into planets, meaning that Luu, in effect, helped reveal the most pristine material yet to be found from the solar system's creation 4.6 billion years ago. At the same time, she was fulfilling the dream of many planetary astronomers; she was extending the borders of the solar system for the first time since Clyde Tombaugh identified Pluto in 1930.

> *"I packed my colored pencils in secret, worried that my parents would consider them too frivolous."*

For Jewitt, the discovery was the highlight of a vocation that he has pursued since childhood. For Luu, though, it was an unforeseen development in a career filled with curious twists and turns, a life that has taken her from the war-torn country of Vietnam to an assistant professorship at Harvard University.

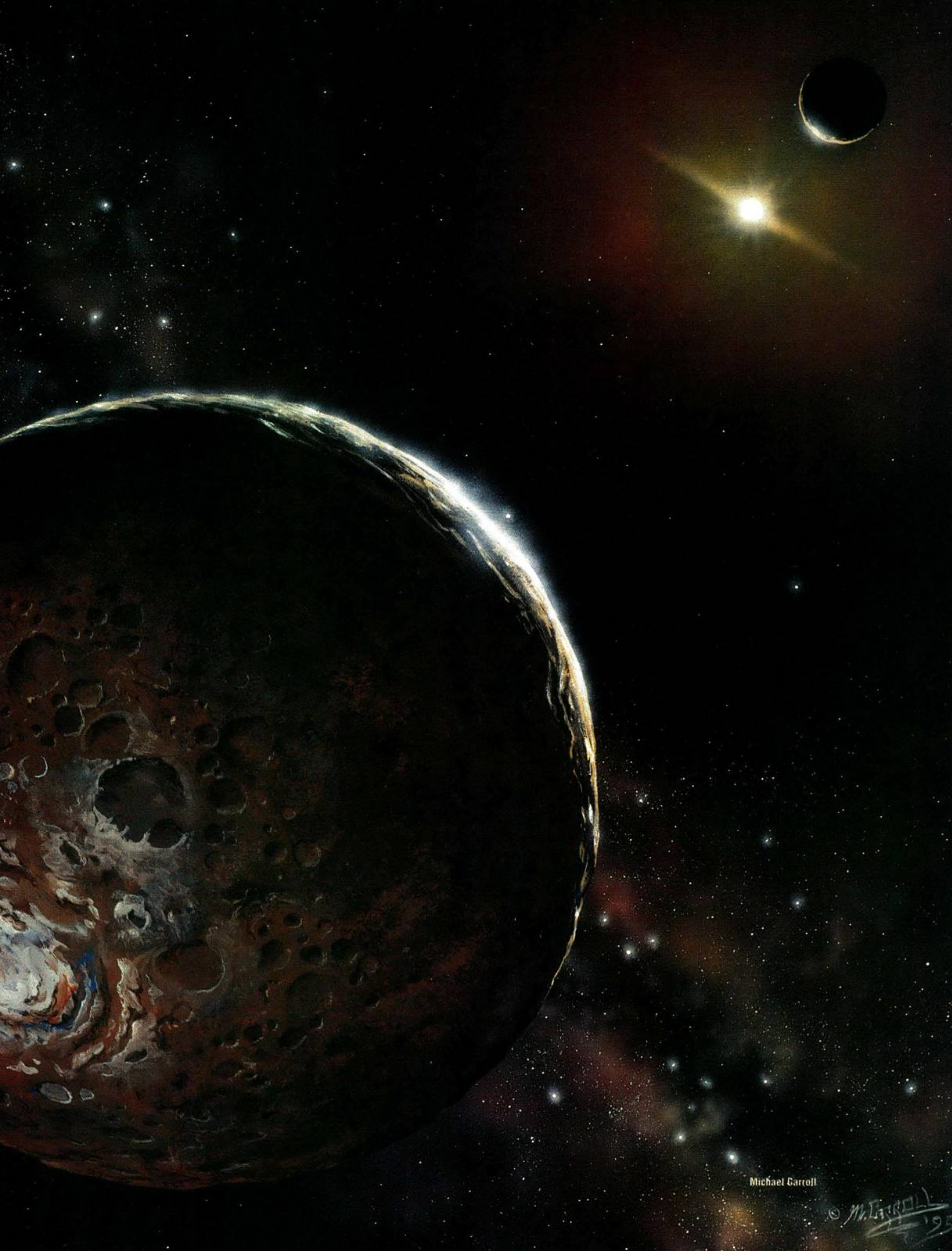
Born in Saigon in 1963, Luu vividly recalls the continual military strife that surrounded her as a child. She saw it as a way of life. "When my parents spoke back then of the peaceful times of their childhood, it was like listening to a fairy tale," she says. Her father worked as an interpreter and liaison between the American forces and the South Vietnamese government. Though his pay was meager, he made sure to send his two sons and two daughters to school, then a costly privilege in Vietnam.

Luu's life literally changed overnight in April 1975 as the North Vietnamese army entered Saigon. Without warning, her father came home and announced that they had to flee the country the very next day. Each child was allowed to take one bag, just enough room for a change of clothes and the barest necessities. "I packed my colored pencils in secret, worried that my parents would consider them too frivolous," recalls Luu.

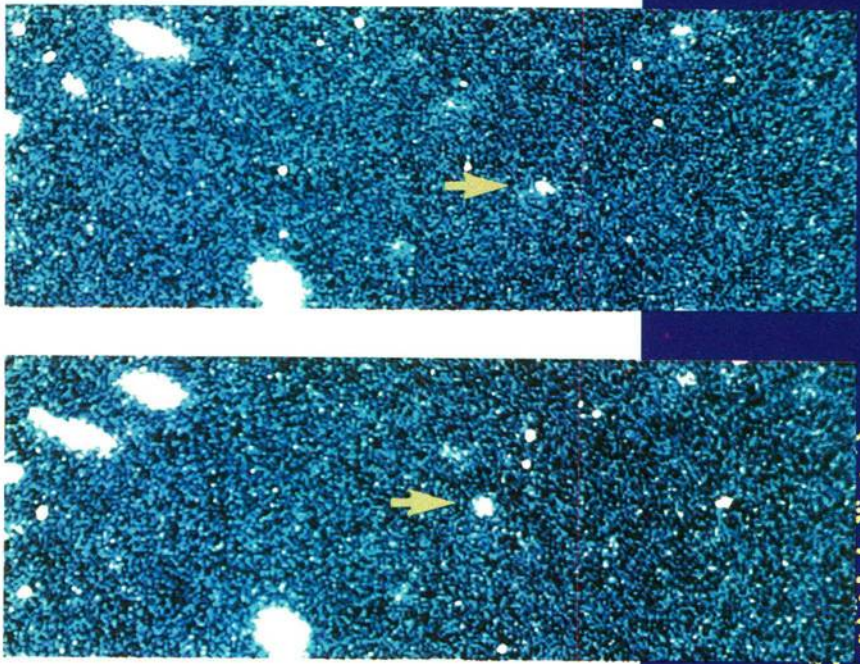
Escaping Vietnam by plane, the Luus eventually settled in southern California, where a host family promptly Americanized their names. At the age of 12, Luu Le Hang officially became Jane Luu. Already fluent in French, given her Vietnamese background, Luu learned English over her first summer in America. By high school she was displaying a nimble proficiency in her scientific courses and graduated as valedictorian. A scholarship, combined with student loans and a work-study program, enabled her to attend Stanford University, where she majored in physics.

Serendipity led her to astronomy. "Before going off to graduate school in physics, I decided to

LURKING BEYOND PLUTO are ten billion Kuiper disk objects, like this one.

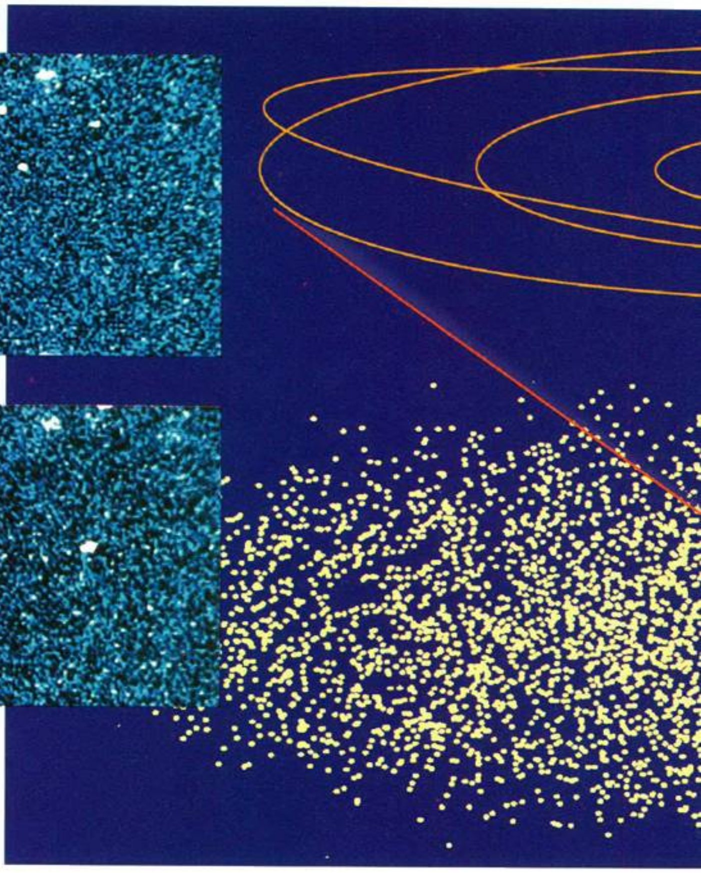


Michael Carroll



David Jewitt and Jane Luu

EUREKA! Above is the first object ever seen orbiting the Sun beyond Pluto. David Jewitt and Jane Luu discovered the 280-km-wide object, named QB_1, by observing its motion in these two images. QB_1 is the first object to be found in the Kuiper disk (right).



work for a while at NASA's Jet Propulsion Laboratory," explains Luu. "It was a simple job, running computer programs." But each day, in her walks about the Pasadena complex, she would admire the stunning pictures of the solar system's moons and planets that lined the corridors of JPL, headquarters for the Voyager missions to the outer planets. She was hooked and soon switched her loyalties from physics to planetary astronomy. "I find the solar system far more appealing than extragalactic objects," says Luu. "In this field, we can take pictures up close."

By 1990 she obtained a doctorate from MIT, although her last two years as a graduate student were spent largely at the University of Hawaii, where her MIT thesis advisor David Jewitt had transferred. For her dissertation, Luu investigated the relationship between comets and asteroids. But on the side, she joined Jewitt in his search for the "Holy Grail" of planetary astronomy — objects beyond Pluto.

In 1951 the Dutch-American astronomer Gerard Kuiper — the father of modern planetary astronomy — argued that a disk-shaped swarm of protocomets must lie in the plane of the solar system, just past the outer planets and extending outward ever thinner for billions of kilometers. "Kuiper saw no reason for the solar system to stop abruptly at Pluto," points out Luu.

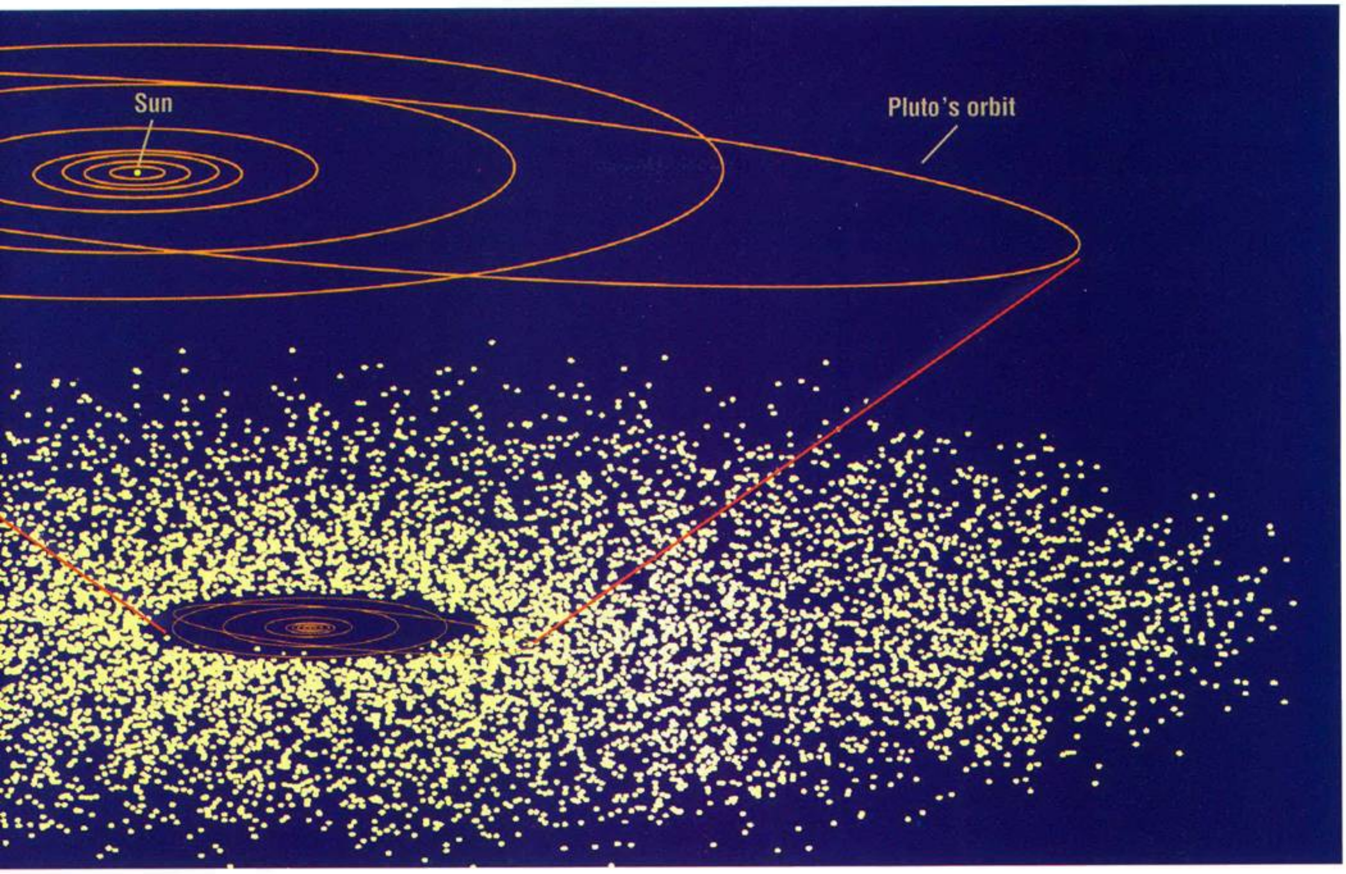
In Kuiper's day, looking for cometary bodies beyond Pluto seemed pretty hopeless, like trying to spot lumps of coal in a pitch-black room. But by the 1980s astronomers developed renewed interest in the idea. For one, the space-based Infrared Astronomical Satellite (IRAS) began to spot circumstellar disks around other stars, such as Vega. And theorists running computer simulations were seeing that the short-period comets (comets with periods shorter than 200 years) would likely originate in a Kuiper-type disk.

In 1987 Jewitt also realized that new technologies, especially the arrival of sensitive charge-coupled devices (CCDs) — digital cameras — at last made looking for these faint objects worthwhile. Moreover, speedier computer processing allowed Jewitt and Luu to examine their images at the telescope in real time, a necessity for tracking and confirming a find.

Rewards were far from immediate, though. Jewitt and Luu looked for five years and saw nothing. Mean-

David Jewitt and Jane Luu

THE DISCOVERERS, Jane Luu and David Jewitt at the University of Hawaii's 2.2-meter telescope.



while, Luu graduated and moved on to a postdoctoral position at the Center for Astrophysics. Over these years, the survey continued. They worked as a cohesive team, with Jewitt usually pointing the telescope and Luu operating the computer and CCD. Their strategy was to look at the dark, outer regions of the solar system two times a year, in March and September, when the bright glow of the Milky Way is not obstructing the ecliptic, the plane of the solar system. It was a big gamble, and they knew it. Indeed, Jewitt and Luu were denied time on national telescopes, since the odds for spotting an object beyond Pluto were considered too low.

The turning point came when Jewitt was able to use a new CCD recently mounted on the University of Hawaii's 2.2-meter telescope atop Mauna Kea, which offered a clearer view than their previous observing site on Kitt Peak in Arizona. More important, the new CCD was twice as sensitive, and its field of view was four times greater than their previous one, enabling them to spot fainter objects in a larger patch of sky.

Results came swiftly. On August 30, 1992, just their second night using the new camera, Jewitt and Luu spotted something. "Our procedure was to take three consecutive images of a region, each exposure taking 15 minutes. And then we would 'blink' them," says Luu. In other words, they would switch quickly from one picture to the next on the computer monitor and see if anything had moved from frame to frame.

"I don't like to blink after just two images because there can be so many false candidates, like two cosmic rays that happen to be near each other. But Dave is very gung ho about this," explains Luu. "On that night he immediately started blinking with two images and said, 'Jane, come look at this.'"

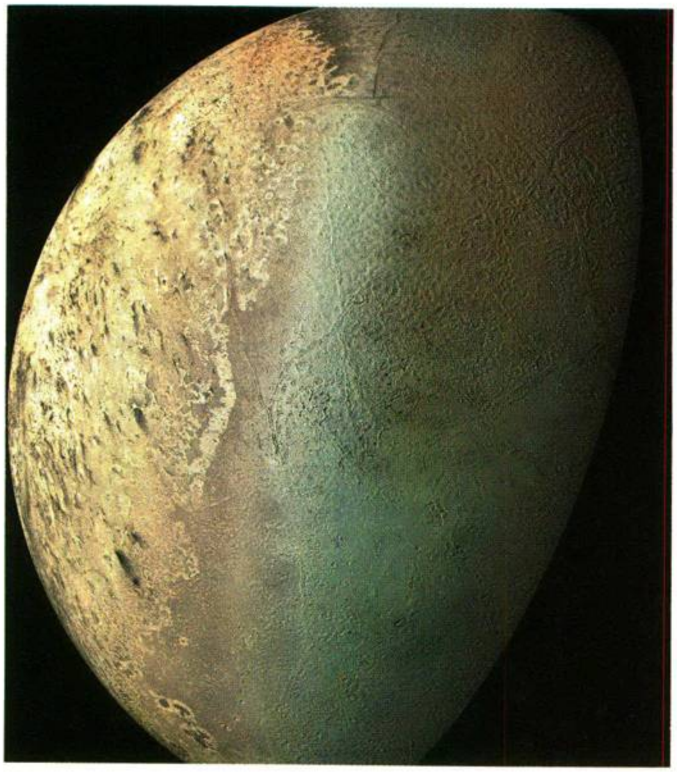
They saw something that didn't look like the dot-like imprint from a cosmic ray. Instead of being a sharp spot, it was rather fuzzy. They took a third image and saw that the 23rd-magnitude fuzzy spot had moved farther along. "We told each other to calm down and within a couple of hours took a fourth image," says Luu. "We didn't dare hope for too much because we had been doing this for five years."

In fact, they didn't report their find until they confirmed the sighting on the remaining nights of their five-day observing run. Its official name became 1992 QB_1, but Jewitt and Luu had already nicknamed it "Smiley," after the noted spy in a series of John Le Carré spy novels. It was a fitting name for a cosmic intruder lurking in the dark reaches of space.

Jewitt and Luu nicknamed QB_1 "Smiley" after the noted spy in a series of John Le Carré novels.

1992 QB_1 revolves around the Sun in a near-circular orbit at a distance of 6.6 billion kilometers (or 44 astronomical units in astronomers' parlance, 1 AU being the average distance between the Earth and the Sun). With a diameter of 280 kilometers, 1992 QB_1 is roughly one-eighth as wide as Pluto.

Six months after the discovery of 1992 QB_1, Jewitt and Luu spotted a similar object in another part of the sky and christened it "Karla," Smiley's nemesis. The next three they found also got monikers care of Le Carré: Control (Smiley's boss); Hayden (a double


NASA

INTERLOPER from beyond. Neptune's satellite Triton probably originated in the Kuiper disk and was captured by the planet.

Centaurs

Object	Minimum Distance from Sun	Maximum Distance from Sun	Average Distance from Sun	Eccen.	Inclin.
Saturn	9.02	10.09	9.55	0.056	2.5
Uranus	18.33	20.11	19.22	0.047	0.8
Chiron	8.45	18.97	13.71	0.383	6.9
Pholus	8.69	31.96	20.32	0.573	24.7
1993 HA$_2$	11.82	37.70	24.76	0.523	15.6
1994 TA	10.69	24.84	17.76	0.398	5.4
1995 DW$_2$	18.83	30.87	24.85	0.242	4.2
1995 GO	6.78	32.12	19.45	0.651	17.5

Transneptunian Objects

Neptune	29.84	30.38	30.11	0.009	1.8
Pluto	29.58	49.39	39.54	0.250	17.2
1992 QB$_1$	40.87	47.15	44.01	0.071	2.2
1993 FW	41.56	46.04	43.80	0.051	7.7
1993 RO	31.49	47.36	39.42	0.201	3.7
1993 RP	34.86	43.80	39.33	0.114	2.6
1993 SB	26.75	52.16	39.45	0.322	1.9
1993 SC	32.14	47.19	39.67	0.190	5.2
1994 ES$_2$	39.84	52.09	45.96	0.133	1.1
1994 EV$_3$	41.32	44.71	43.01	0.039	1.7
1994 GV$_9$	41.89	45.43	43.66	0.041	0.6
1994 JS	32.70	53.07	42.88	0.238	14.0
1994 JV	35.25	35.25	35.25	0.0	18.1
1994 JQ$_1$	43.00	45.28	44.14	0.026	3.7
1994 JR$_1$	34.74	44.91	39.83	0.128	3.8
1994 TB	26.89	52.07	39.48	0.319	12.1
1994 TG	42.25	42.25	42.25	0.0	6.8
1994 TH	40.94	40.94	40.94	0.0	16.1
1994 TG$_2$	42.45	42.45	42.45	0.0	2.2
1994 VK$_8$	43.45	43.45	43.45	0.0	1.4
1995 DA$_2$	32.14	40.55	36.35	0.116	6.6
1995 DB$_2$	40.58	46.41	43.49	0.067	4.3
1995 DC$_2$	45.21	45.21	45.21	0.0	2.1
1995 FB$_{21}$	42.43	42.43	42.43	0.0	0.7
1995 GJ	39.01	46.81	42.91	0.091	22.9
1995 GA$_7$	34.75	44.16	39.46	0.119	3.5
1995 GY$_7$	41.35	41.35	41.35	0.0	0.9
1995 HM$_5$	32.52	46.55	39.53	0.178	4.6
1995 KJ$_1$	43.47	43.47	43.47	0.0	2.7
1995 KK$_1$	31.98	46.97	39.48	0.190	9.3

agent); and Anne (Smiley's wife). But the unofficial nicknames had to stop once the list started growing too speedily. At the time this article went to press, 28 large objects have been sighted, situated between 35 and 46 AU. Jewitt, Luu, and University of Hawaii graduate student Jun Chen discovered 21 of them. And as the known population grows, astronomers are building a more confident picture of the Kuiper disk.

The disk's total population could consist of as many as ten billion objects, most of them small, but a few tens of thousands are likely to be at least 100 kilometers across. The fact that the Kuiper disk is not perceptibly tugging on the Pioneer and Voyager spacecraft as they fly through the outer solar system suggests that no more than five Earth masses can be tied up in the disk.

This past June astronomers using the Hubble Space Telescope reported they may have sighted some of the smaller bodies, comet-sized chunks about ten kilometers wide (see "First Drops in a Comet Reservoir," October 1995). Luu and Jewitt are hoping to check this finding with the 10-meter Keck Telescope on Hawaii's Mauna Kea. At 28th magnitude, such objects should be observable with Keck. If confirmed, this would prove that short-period comets originate in the Kuiper disk.

"The things that astronomers are learning about the Kuiper belt are beyond what we had dreamt," says Luu. "When we started on our survey, we just wanted to know if the outer solar system was empty. And if so, why? But now some very interesting questions are being answered by the new evidence."

There's the matter of Pluto, for instance. "The confirmation of the Kuiper belt changes our perception of the solar system," says Luu. "What we thought of as a planet is probably just the biggest member of a rather large population of objects." Pluto moves in a particular orbit — a special "resonance" at the innermost edge of the Kuiper disk — that remains quite stable as it weaves in and out of Neptune's orbit. Pluto orbits the Sun twice each time Neptune goes around three times.

Pluto's moon, Charon, likely came from the Kuiper disk as well. Indeed, several of the Kuiper-disk objects that Jewitt and Luu have discovered are in stable orbits at distances similar to Pluto's (around 40 AU), which inspired Jewitt to dub them "Plutinos." In a way, Neptune acts as a gravitational shepherd, its very presence at a distance of 30 AU from the Sun sets up a series of stable and unstable orbits within the Kuiper disk.

The objects in unstable orbits are prime candidates to become future comets, specifically the short-period comets that periodically orbit the Sun every 20 or so years in the inner regions of the solar system. Computer simulations suggest that Neptune acts as the gatekeeper, its gravity drawing the cometary bodies in from the Kuiper disk and setting them up in an orbital dance around the outer planets. If these objects survive and get near Jupiter, though, their fate is sealed:

Jupiter's powerful gravitational pull either sends them in toward Earth, ejects them out of the solar system entirely, or, like Shoemaker-Levy 9, captures them once and for all.

> "I don't think it would have been possible anywhere else to go from a refugee to a professorship."

Theorists have been modeling these movements on computers for years and are elated by the new wealth of observational data. Jewitt credits Luu for forging unifying links between objects that were once considered separate and distinct in the outer solar system. "I'm pretty critical, but this description fits — she's a superstar," asserts Jewitt. "She's building bridges in a pioneering field."

The once mysterious object named Chiron particularly interests Luu (see "Chiron: Interloper from the Kuiper Disk," August 1994). Discovered in 1977 out near Saturn, this interloper was first classified as an asteroid, even though it was far from an asteroid's usual territory, the vast expanse between Mars and Jupiter. But a decade later reports came in that Chiron was fluctuating in brightness, a sure sign of cometary activity. Five other objects that cross the orbits of the giant planets have since been found: Pholus, 1993 HA_2, 1994 TA, 1995 DW_2, and 1995 GO. To Luu and others, these objects, now called Centaurs, serve as the missing links between the Kuiper disk and short-period comets; they are the latest icy chunks to have left the disk and ventured into the established solar system.

"Pholus gained fame because it was so red," points out Luu, "one of the reddest things in the solar system after Mars." Laboratory studies suggest that organic materials have built up over the icy body due to irradiation by the high-energy particles that fly about in space. Interestingly, 1992 QB_1 is also very red, which means it may share a common origin with Pholus.

"What we're most likely seeing in these Kuiper belt objects are pristine comet nuclei before they develop their obscuring coma," explains Luu. But the Kuiper disk objects are not all red; the bodies detected so far, in fact, display a wide variety of colors. It's possible that whenever some of these objects collide they are fracturing their outer mantles and exposing their interiors to various degrees.

"These objects," says Luu, "are the most primitive material to be found in the solar system, formed when the solar system was born. So, by studying them, we get to look back in time, much the way cosmologists look back in time by observing more and more distant galaxies. Theoretically, we might be able to work backward and determine what the original solar nebula was like."

The following sites on the World Wide Web provide up-to-date orbital information on Centaurs and Trans-Neptunian objects:

http://cfa-www.harvard.edu/cfa/ps/lists/Centaurs.html
http://cfa-www.harvard.edu/cfa/ps/lists/TNOs.html

Jon Chase/Harvard University

With the discovery of 1992 QB_1, Luu's professional life was soon devoted to the study of the Kuiper disk, first as a Hubble Fellow at Berkeley and Stanford and now as an assistant professor at Harvard. But travel is her passion. It's the one subject, aside from science, that she talks about with ease and a ready smile. Her travel stories are plentiful: her prowess at moving about Europe without a passport as a student; her visit to Nepal during monsoon season; a trek to Tibet and her first taste of yakburgers. She recently returned from a trip to Mongolia.

Each exotic journey only reaffirms to her what it means to reside in America, where a foreign ancestry is more readily accepted. "I don't think it would have been possible anywhere else to go from a refugee family to a professorship at a prestigious university," she says. Recent cuts in government-sponsored research, the kind that supported her rise through the academic ranks, greatly concern her. "I worry how it will affect the education of less-privileged young people. I know what it's like for them firsthand."

Currently, she and Jewitt are extending their searches and tracking down the details of the Kuiper-disk objects: their colors, shapes, rotational characteristics. Jewitt and Luu's collaboration has now lasted nearly a decade. "We're well matched," says Luu. "When we get to the telescope, we have the routine down pat. David watches over the instrumentation, such as setting up the filters and such, while I take care of the computing." Only the choice of CDs is a bone of contention: Jewitt, five years older than Luu, likes to listen to his deathcore rock music while observing ("It's the kind of music that Bob Dole and his pals would like to ban," says Jewitt). Luu, who plays the cello, prefers classical.

But whatever their choice of music within the control room, their work is allowing the music of the spheres to be heard a little farther out, past Pluto and beyond. □

Massachusetts-based science writer Marcia Bartusiak has been reporting on physics and astronomy for more than a decade. Her most recent book, Through a Universe Darkly *(HarperCollins/Avon), discusses the search for the elusive dark matter.*

OF WORMHOLES TIME MACHINES AND PARADOXES

Imagine entering a wormhole, emerging in the past, and taking yourself out for the premiere of *Back to the Future*. Physicists are beginning to think it may be possible.

by J. Craig Wheeler

"Time is the fire in which we burn." This quote from the most recent *Star Trek* movie embodies the hold that time has on our imaginations. Time has been a frequent subject in science fiction, especially the fascinating and philosophically thorny issue of time travel. Although ultimate understanding of time and its manipulation remain beyond our grasp, physicists have brought the issues to focus in a remarkable story of the exploration of time that has been carried out for the last few years.

Time has always been a fundamental part of physics. The equations physicists use are chronologically symmetric — in other words, they do not differentiate a forward from a backward direction in time. If you took a movie of particles in Brownian motion and then ran it backward, you would not be able to tell the difference. If, on the other hand, the projectionist ran an episode of *Star Trek* backward, there would be howls of protest from the audience. Where does the "arrow of time" arise? Why is it that we age from 18 to 38 to 58, but not the other way around? Is that progression immutable?

Time and special relativity: If two observers are in uniform motion, each will see the other aging more slowly.

The latest chapter in physicists' attack on time travel arose from a work of science fiction. In the original version of Carl Sagan's novel *Contact*, he invoked a means of interstellar travel left by an ancient civilization for Earthlings to discover. Effectively, he wanted his passageway to be a black hole, where you flew into the event horizon and emerged — elsewhere. Sagan sent the draft of the book to his friend and colleague, Kip Thorne. Thorne, a physicist at Caltech, is one of the world's experts on black holes. In fact, he has written his personal version of this story in a recent book entitled *Black Holes & Time Warps: Einstein's Outrageous Legacy*.

Thorne realized that Sagan's proposed method was flawed. The solution required both different physics and more imagination.

In the solution for Einstein's equations for a black hole, a passage can exist between two universes or between two parts of the same universe. Physicists call such a structure an "Einstein-Rosen" bridge. In more casual parlance, this bridge is called a wormhole. It has been known for years that in the standard mathematical solution the apparent wormhole in the black-hole solution represents only a single moment in time. Just before or just after that instant, there was no passage, only the terrible maw of the singularity, waiting to destroy anything that passed into the event horizon. Furthermore, if you tried to race

Free will and time machines: If time machines exist and the consistency conjecture holds, then is everything pre-ordained, and there is no free will?

Anglo-Australian Telescope Board

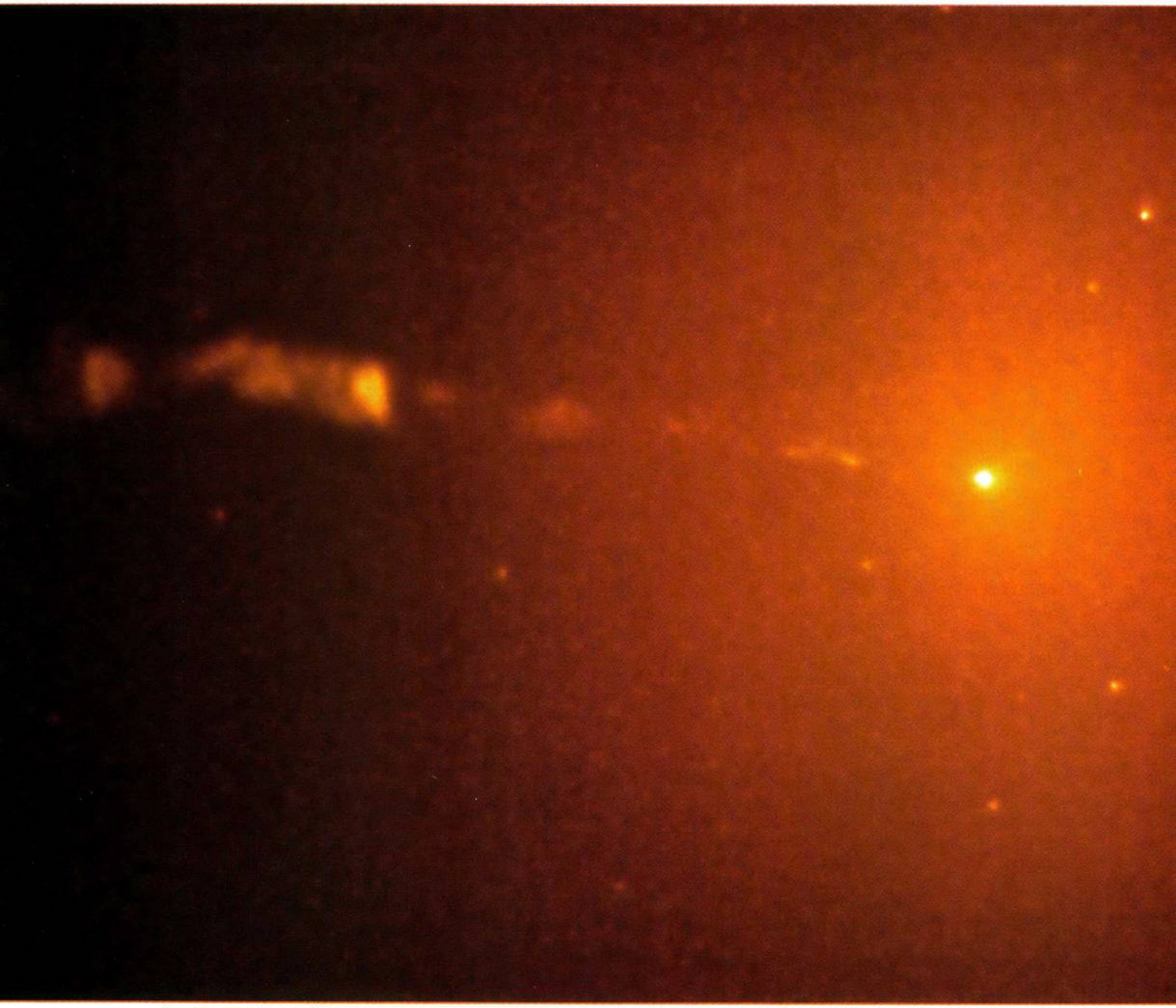
through the wormhole in the instant it opened at anything less than the speed of light, the wormhole would snap shut, trapping you and sending you into the singularity. Abandon all hope, ye who enter here!

As he mused further, however, Thorne realized that there might be another approach. Suppose one were dealing with an arbitrarily advanced civilization, the citizens of which could engineer anything that was not absolutely forbidden by the laws of physics. What is possible under those circumstances?

Thorne's solution involved what physicists loosely call "exotic matter." Ordinary matter has a finite energy and exerts a finite pressure and creates a normal, pulling, gravitational field. One can envisage, however, matter that has a negative energy, that exerts a negative pressure, like the tension in a rubber band, but raised to such an extreme level that the tension energy is greater than the rest-mass energy, $E = mc^2$, of the rubber band. It has the property one would label "antigravity." Whereas ordinary matter pushes outward with pressure and pulls inward with gravity, such exotic matter pulls inward with its "pressure" and pushes outward with its gravity.

Related stuff has become a prominent topic in cosmology. Physicists describe an inflationary phase occurring in the split seconds after the big bang, in which the universe undergoes a rapid expansion that leads to its current size and smoothness. The condition responsible for inflation is known as a false vacuum. This was the brief state of the universe when the electromagnetic and nuclear forces were indistinguishable from one another. Although not exotic, the false vacuum exerted a negative pressure and a repulsive grav-

WHERE PHYSICS BREAKS DOWN
The giant elliptical galaxy M87 (top) is one of the nearest active galaxies to the Milky Way. At its core lies an object that defies the laws of physics.



Space Telescope Science Institute.

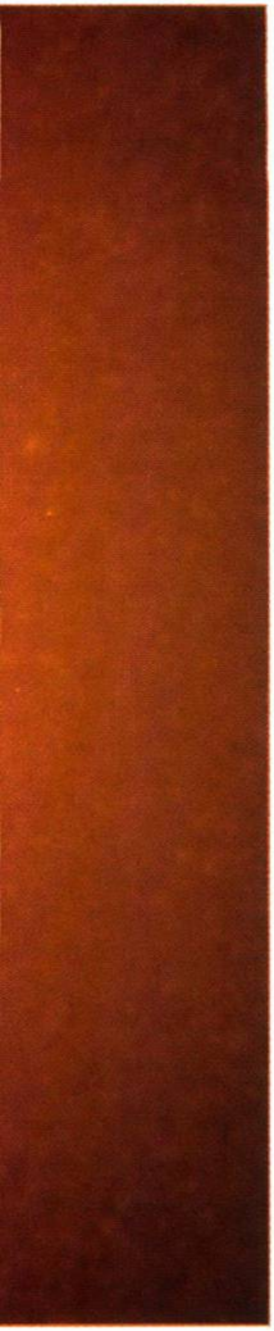
The bright central region consists of a disk of hot gas. This disk is thought to be the source of the 5,000-light-year-long plasma jet seen shooting out of the core region.

itational field. The exotic matter needed to create wormholes would have to display these same characteristics, only to a greater degree.

In his comments to Sagan, Thorne speculated, that an advanced civilization could slather some of this stuff on a mortar board, pick up a trowel, and make something of it. What could you make? The answer was that you could line an Einstein-Rosen bridge with it and hold the bridge open indefinitely, thanks to the repulsive nature of the gravity of your exotic cement! The way was open conceptually to traverse through hyperspace from one place in the Galaxy to a very distant one in an arbitrarily short amount of time. Faster-than-light travel through a wormhole. That was enough for Sagan. He adopted that basic outline and described such a wormhole in the book that went to press.

It was not enough for Thorne, however. He continued thinking about the problem. He worked with students on it and together they published a number of papers showing that a proper arrangement of exotic matter could lead to a stable, permanent wormhole.

What would a wormhole look like? That would depend on how it was constructed. In its simplest form it might appear spherical from the outside, that is, all approaches from all directions would look the same. The boundary of the wormhole would not necessarily look black, like a black hole, even though the outer structure of their space-time geometries were similar. A black hole has an event horizon from within



Time machines: if wormholes exist, then they can, in principle, be used to make a time machine through the twin-paradox mechanism. After one end of the wormhole is accelerated and returned, it will thereafter be absolutely younger than the mouth of the wormhole that remained in uniform motion.

which nothing can escape. You can, in principle, see through a wormhole. If you traveled through one you would head straight toward the center of the spherical space. Without changing the direction of your propagation you would eventually find yourself traveling away from the center, to emerge in another place.

From inside a spherical wormhole, the perspective would be tunnel-like. You would be able to see light coming in from the normal space at either end of the wormhole. The view sideways, however, would seem oddly constricted. There could be two reasons for this. Even in portions of the wormhole's space-time that were vacuum — empty space — the space is highly curved. This would mean that light heading off in any direction "perpendicular" to the radius through the center of the wormhole would travel straight in the local space, but end up back where it started, like a line drawn around the surface of a sphere, only in three-dimensional space. Hence, if you faced sideways in a wormhole you could, in principle, see the back of your head.

In practice the light might be distorted and your view very fuzzy. The effect might look like a halo of light around you that differentiated the "sideways" direction from that straight through the center of the wormhole. In some portion of the wormhole there would have to be a three-dimensional volume of exotic matter to hold it open. There would have to be a tunnel through this exotic matter if you were to be able to pass through. This portion of the wormhole might look literally like a tunnel.

The obvious, tunnel-like aspects of a wormhole are not to be confused with the funnel diagrams that physicists use to make a two-dimensional representation of the real three-dimensional space around a black hole or wormhole. There, a circle in two-dimensional space is the analog of a sphere in three-dimensional space and the real curved space around a wormhole is represented by a stretched two-dimensional space that resembles a funnel. You cannot travel through the mouth of the funnel. That is a third-dimensional hyperspace in the two-dimensional analog. You have to crawl spider-like along the surface of the two-dimensional space to get the true meaning of the nature of that space and some feeling for the three-dimensional reality.

Grandfather paradox: The notion that with a time machine causality can be violated and an event, like traveling back in time to kill your grandfather, can be neither true nor untrue.

Movies portray wormholes in various ways. The more recent ones are based on some of these modern notions, but there may also be a tendency to confuse the actual tunnel-like nature with the two-dimensional funnel-like analog. In the first *Star Trek* movie, the Enterprise is captured in a wormhole when it jumps into warp drive too soon after leaving Earth. When you watch the film again, notice that you can see stars through the sides of the wormhole. That is definitely wrong. Light from stars could come in the end of the wormhole you entered, or it could come in through the opposite end in which you are headed, but inside the wormhole, light is trapped by the severe curvature of the space. There is no literal tunnel wall and hence you cannot look "sideways" through it.

The twin paradox: if one twin remains stationary and the other is accelerated to near-light speed, either by traveling out and back or by venturing into a stronger gravity field, then the twin who has experienced the acceleration will be absolutely younger.

In the TV series *Babylon 5*, there is a "constructed" wormhole, but its whirlpool-like nature may draw more on the two-dimensional analogy than the manifestation in real space. In another TV series, *Deep Space 9*, the wormhole can be approached from any direction and the tunnel-like interior is as close to reality as one can expect from graphic designers appealing to a TV audience.

The classic wormhole is that in the movie *2001: A Space Odyssey*. There, the exterior of the wormhole looks like a flat, rectangular monolith. Matt Visser of Washington University of St. Louis has designed a wormhole that looks much like that, with the exotic matter confined to struts along the boundaries of the rectangular body.

The modern story of wormholes does not stop there, however. As they thought about the nature of wormholes more, Thorne and his coworkers realized that wormholes would also function as time machines. In this phase, Thorne was joined by Igor Novikov, then of Moscow, now at the University of Copenhagen, and his colleagues. Special relativity has long since taught us the lesson of the "twin paradox." A pair of twins moving at some velocity with respect to one another will each measure the other to be aging more slowly. What happens when one of the twins rockets out into space and then returns while the other remains home? The motion is relative, but how can both be younger?

The resolution is that the one that traveled will be younger. That traveler experienced a force, an acceleration upon turning around, and that makes all the difference. Thorne realized that you could do this experiment at the two ends of a wormhole. Grab one end (gravitationally) and rocket it out and back. It will be absolutely younger than the end that was not accelerated. Novikov argued that you can do the same thing by putting one end of a wormhole in empty space and the other near a gravitating body. General relativity says that time will flow more slowly in the gravity well.

In either of these arrangements, you have a time machine. You can walk into one end of the wormhole and emerge at an earlier era, albeit not one before the wormhole time machine was created. If you walk to the other end of the wormhole though, the exterior space-time passes normally. You could meet your younger self emerging from the hole!

Resolution of pool ball crisis: Novikov, Thorne, and associates showed that the pool ball problem satisfies the consistency conjecture. No case was found that gave rise to a paradox. The past and future pool balls could just "kiss" with a slight deflection of the trajectory, but a "hard" collision with the first pool ball being knocked away from the wormhole, thus producing a paradox, simply did not and cannot arise.

Is this possible? Do the laws of physics allow such things? What happens to causality? These questions lead to another classic paradox, one that has been explored thoroughly in science-fiction literature and continues to be a common theme in TV and movies: the "grandfather paradox." The notion is that a time traveler goes back in time and kills her grandfather before her mother (never mind herself) was born. Thus, the paradox. Thorne argues that this example is too paternal and has the time traveler kill her mother, thus the "matricide paradox." Novikov argues for leaving out the middle-man. Kill your younger self in a time-contorted suicide. The result is the same. The time traveler could not have existed in the first place to commit the array of crimes.

All these examples require people to make them substantive, but people raise the issue of consciousness and free will and those issues are messy for a physicist. Joe Polchinski, then of the University of Texas at Austin, invented a simple mechanical paradox. Physicists are fond of referring to "pool-ball" physics, meaning reducing a problem to something as visceral as pool balls bouncing off one another so that the physics — conservation of momentum, for instance — can be easily visualized. Polchinski dipped into this analog to present the "pool-ball crisis." In this thought experiment a pool ball rolls into one end of the wormhole time machine. It comes out the other end in the past. It smacks its earlier incarnation, deflecting it so that it does not enter the wormhole. So how does it "get there" in the future if it never entered in the past? Is this simple mechanical paradox valid?

No, counter the time-machine explorers. The flaw in this argument, according to Novikov, is that one posits the original pool ball rolling unimpeded into the wormhole and only speaks about the collision when it emerges to collide with itself. That is self-inconsistent. The original pool ball must be involved in the collision when it first rolls toward the hole opening.

Novikov consistency conjecture: The conjecture that physics must be self-consistent and simply does not allow paradoxes even if time travel exists.

Chronology notwithstanding, physics must be self consistent. That is the only criterion. Novikov and his colleagues have carefully studied the pool ball crises and have shown that it cannot arise. They have looked at every conceivable interaction. Pool balls can miss, or they can strike a glancing blow, but they simply can never undergo a hard collision that leads to a paradox. Novikov's group even explored an exploding pool ball, one fragment of which manages to enter the wormhole, come back in time and hit the exploding pool ball to render the whole experiment self-inconsistent. The notion that physics can incorporate time machines in this way is called, in some circles, the "Novikov consistency conjecture."

A close up view of the disk shows a spiral-shaped pattern of gas. Spectroscopic measurements reveal this disk of gas to be swirling around the center at speeds of 550 kilometes per second. From this velocity, astronomers derive a mass for the central object of 2.6 billion Suns. This much mass, however, is concentrated into a space no larger than our solar system. Somewhere within the bright spot in this image, then, lies a place where conventional space and time end.

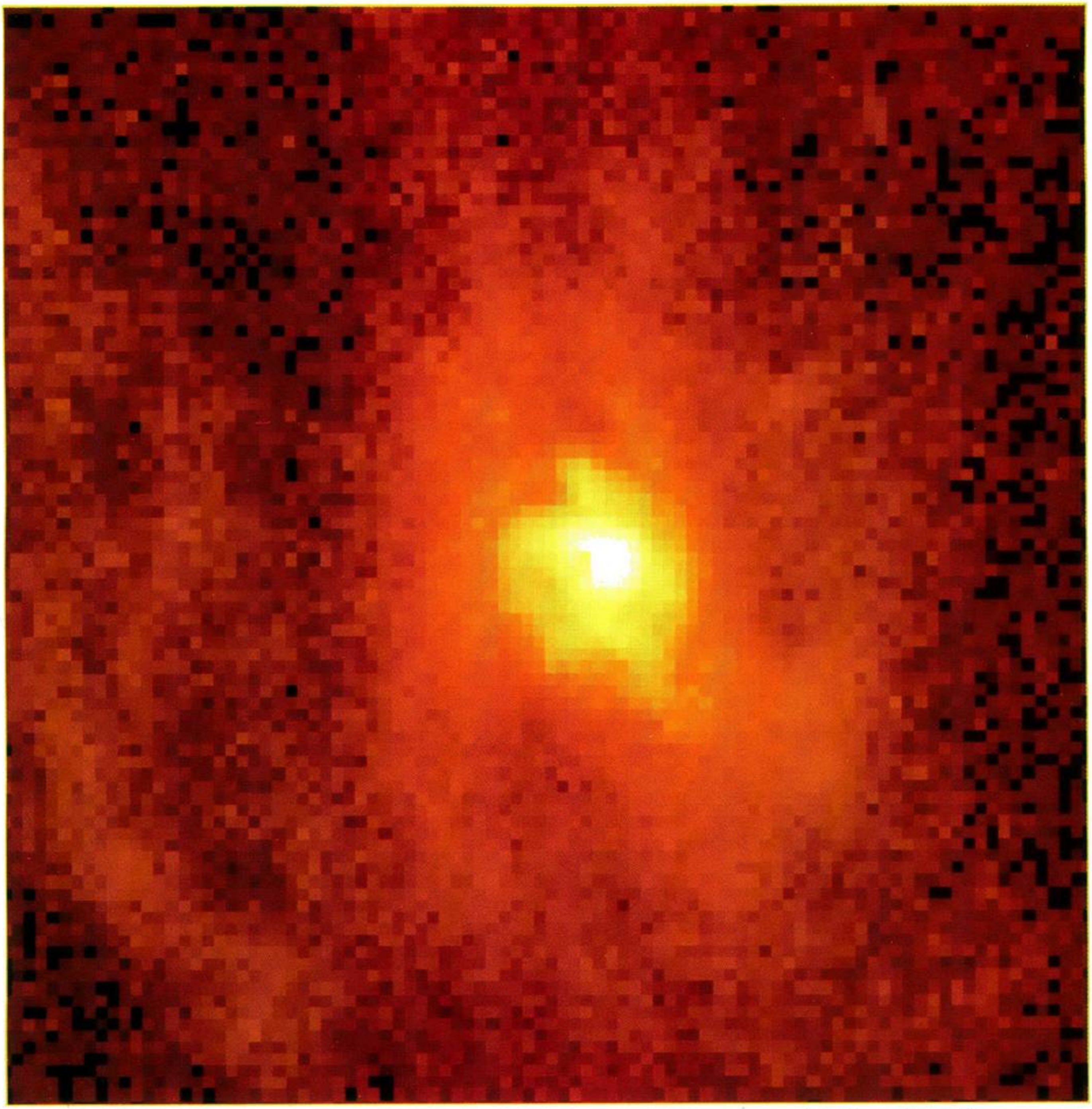
What then of the original paradoxes? What happens with people? According to the consistency conjecture, the complex intrapersonal interactions must work themselves out, like the pool balls, so that there is no paradox. That is the resolution. This means, if taken literally, that if time machines exist there can be no free will. You simply cannot will yourself to kill your younger self if you travel back in time. You can coexist, take yourself out for a beer, celebrate your birthday together, but somehow circumstances will dictate that you can take no behavior that will lead to a paradox in time.

Novikov urges another viewpoint. Physics already restricts our free will every day. You may will yourself to fly, or to walk through a concrete wall, but gravity and condensed-matter physics dictate that you cannot.

Is the converse true? If personal free will exists then time machines cannot? That question is unresolved. (The topic of free will is often up for debate!) The consistency conjecture does say that certain time-travel plots are allowed in stories and movies and others are not. In particular, one cannot change the future, the basic notion behind such movies as *Back to the Future* and *The Terminator*. Loops in time are allowed, but according to the consistency conjecture, the future is as fixed as the past and cannot be affected by an act of will or any other physical act.

Another way to resolve these issues is to say time somehow "forks off" at the moment of a paradox. In one time prong a time traveler lives on, even having killed himself. In this view his younger self lives in the old time prong, but not in the current one. It is not clear that this resolves the origin of the memories the time traveler has of his younger self wielding the knife in the cause of science, of course, at the critical moment.

Philosophical questions aside, there are still issues involved in time-machine research that go right to the heart of modern physics. Investigation shows that wormhole mouths, like the space near the event horizon of a black hole, will emit a natural radiation, called Hawking radiation. In the case of a black hole, this



Space Telescope Science Institute.

radiation leads to the evaporation of the black hole.

For a wormhole the issue is, if anything, even deeper. The Hawking radiation can travel in normal space to the opposite mouth of the wormhole, zip inside, and emerge in the past just as it left. Now there is twice as much radiation. The cycle might repeat indefinitely and build up an infinite energy density, thus sealing off the wormhole or preventing it from having existed in the first place.

To properly address this issue physicists need a full theory of quantum gravity, a theory that incorporates both violently curved space-time and the probabilistic nature of the quantum theory. Such a theory remains the holy grail of modern physics, a theory needed to understand the singularity of the Big Bang and that inside a black hole. There are still great conceptual problems facing the development of such a theory of space-time that applies on scales where time and space themselves are uncertain in a quantum manner, where "up" and "down" and "before" and "after" lose their meaning. Only with the development of an "ultimate theory of everything" will we really know whether time machines are conceptually possible.

Changing the future: If the consistency conjecture is true, then the future cannot be "altered" by current acts.

Or until we find one. □

J. Craig Wheeler is a professor of astronomy at the University of Texas at Austin. His special area of research is supernovae and the astrophysics of black holes.

SKY ALMANAC

Highlights
by Rick Shaffer

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Brilliant Venus looks on as Saturn bids farewell to evening skywatchers by hiding its rings from Earth one more time. Morning's light sees Mercury and the outer planets climb higher into the dawn sky.

by Deborah Byrd

What other planet in the solar system is more fascinating than Saturn? This gas giant world, the crown jewel of the outer solar system, anchors a large and complex system of orbiting rings and moons. For the better part of last year, Saturn held the attention of both amateur and professional astronomers. This month it offers up several interesting sights before disappearing in the Sun's glare.

On February 2 **Saturn** has a spectacular conjunction with the brightest planet of all, **Venus,** low in the western twilight sky. On this evening, the two planets are 1.3° apart on the sky's dome. If you've never seen Saturn, you can't fail to locate it now. Simply look for Venus, the brilliant star-like object low in the western twilight sky. Saturn will be the much fainter object nearby. Just be sure to look for Saturn and Venus not long after the Sun goes down. They are visible a couple of hours after sunset before following the Sun below the western horizon.

At magnitude 1.2, Saturn is much fainter than Venus, even though it is really a much larger world. Saturn has recently been rather inconspicuous to the eye, but the brightness of Venus makes Saturn noticeable in early February.

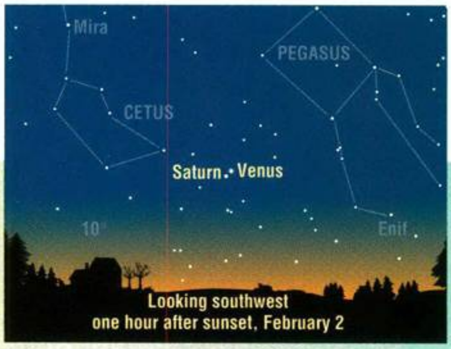
With a dazzling magnitude of –4.1, Venus is much brighter than any other object in the night sky, with the exception of the Moon. This month, as you gaze at these two worlds, remind yourself that sunlight reflecting from Saturn requires nearly an hour and a half to travel back to Earth. Meanwhile, sunlight reflecting from Venus takes less than 10 minutes to cross the inner solar system to Earth.

On February 11, Saturn is noteworthy again for a completely different reason. On this date, for the third time in less than a year and the last time in this century, Earth passes through the plane of Saturn's rings.

Unlike the rings of Jupiter, Uranus, and Neptune, Saturn's rings are broad and bright. When wide open with respect to Earth, they're a vision of almost unbelievable beauty as seen through small telescopes. The rings are less than a mile thick, however, and when they appear edge-on to Earth, telescopes do not reveal them. Then Saturn appears as a large, ringless, golden ball.

Edge-on appearances of Saturn's rings happen twice in every 30-year orbit of this planet. For centuries, the ring-plane passages have been seized upon by

Venus Hails a Sinking Saturn



Looking southwest one hour after sunset, February 2

Quite often as one bright evening planet makes a steady descent toward the horizon, it meets with another planet on the way up. This happens in February when Saturn, quickly racing toward a conjunction with the Sun, pairs up with an ascending Venus in the west after sunset. Don't wait until mid-month to look for the duo; they're only together during the last few days of January and the first few days of February.

The two planets are closest on the evening of February 2, when both stand about 18° above the western horizon as evening twilight ends. On that night they are just over 1° apart, with Saturn being the dimmer object just to the left of brilliant Venus. "Brilliant" isn't an understatement for Venus, for it shines at magnitude –4.0, fully 4.4 magnitudes brighter than Saturn's comparably paltry 0.4. Their difference in brightness is not so hard to understand once you consider Saturn is about ten times farther away from us than Venus.

Though this conjunction of Venus and Saturn is of no scientific interest, amateur astronomers enjoy the sheer beauty of such groupings. On conjunction night, the pure-white, slightly-gibbous disk of Venus forms a striking counterpoint to the butterscotch tones of Saturn's cloud belts. A modest-sized telescope working between 40x and 50x squeezes both planets into the same field of view. This magnification also lets the color contrast stand out well. If your telescope doesn't provide a wide field of view, gently guide it back and forth between the two planets for comparison.
— *Rick Shaffer*

1996

FEBRUARY

1 The Moon is at apogee (252,378 miles from Earth), 10:44 a.m. EST

2 Venus passes 1.3° north of Saturn, 9 p.m. EST (page 56)

4 Full Moon is at 10:58 a.m. EST

11 Mercury passes 0.07° north of Neptune, 9 a.m. EST
Mercury is at greatest western elongation (26°), 4 p.m. EST
Earth passes through the ring-plane of Saturn, 9 p.m. EST (page 61)

12 Last Quarter Moon is at 3:37 a.m. EST

15 The Moon passes 5° north of Jupiter, 10 a.m. EST

16 The Moon passes 5° north of Neptune, 3 p.m. EST
Mercury passes 0.2° north of Uranus, 5 p.m. EST
The Moon passes 6° north of Uranus, midnight EST

17 The Moon passes 5° north of Mercury, 1 a.m. EST
The Moon is at perigee (224,243 miles from Earth), 3:42 a.m. EST

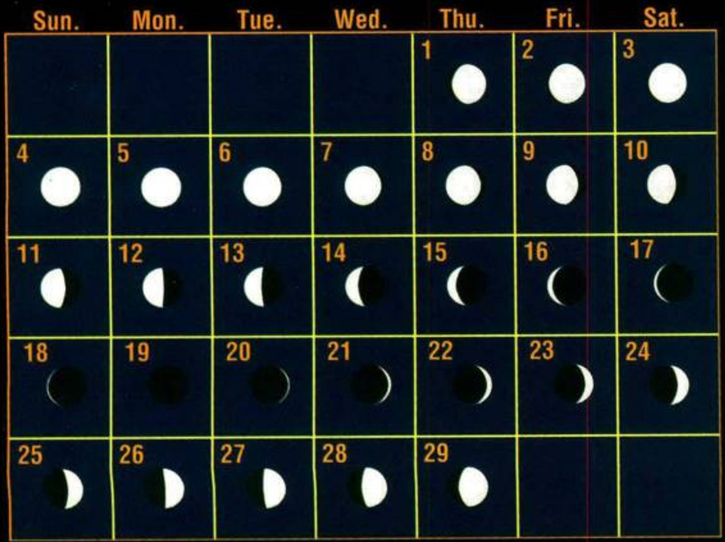
18 Asteroid Herculina is at opposition (page 63)
New Moon is at 6:30 p.m. EST

20 Mars is at perihelion (128.4 million miles from the Sun)
The Moon passes 4° north of Saturn, 2 p.m. EST

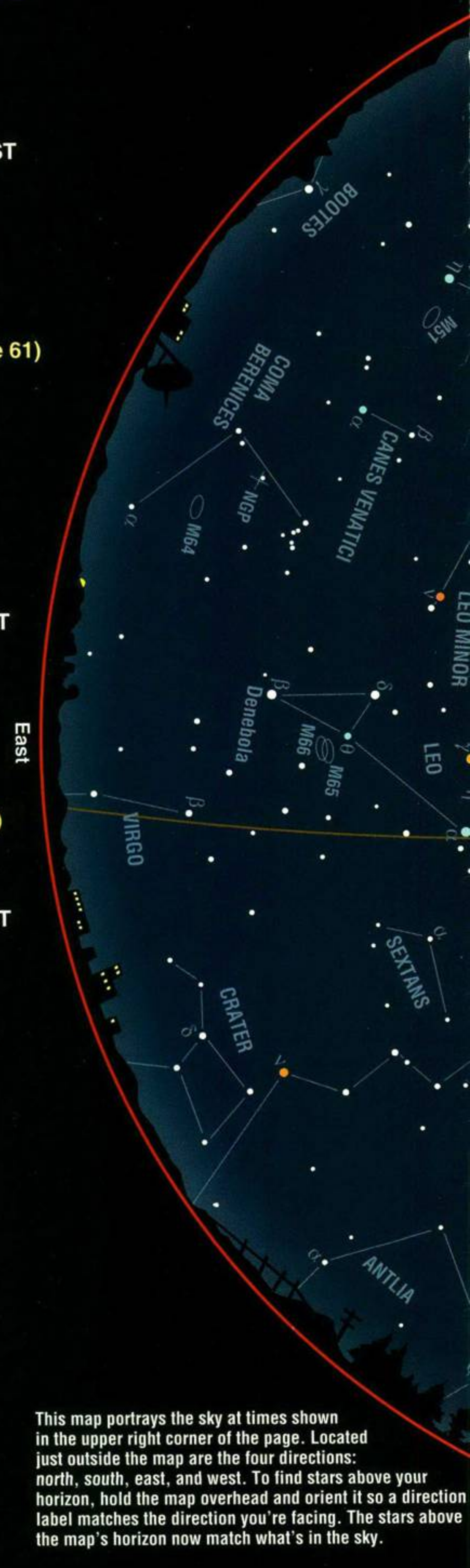
21 The Moon passes 0.06° south of Venus, midnight EST (page 64)

26 First Quarter Moon is at 12:52 a.m. EST

29 The Moon is at apogee (251,826 miles from Earth), 2:08 a.m. EST
Asteroid Nysa is at opposition

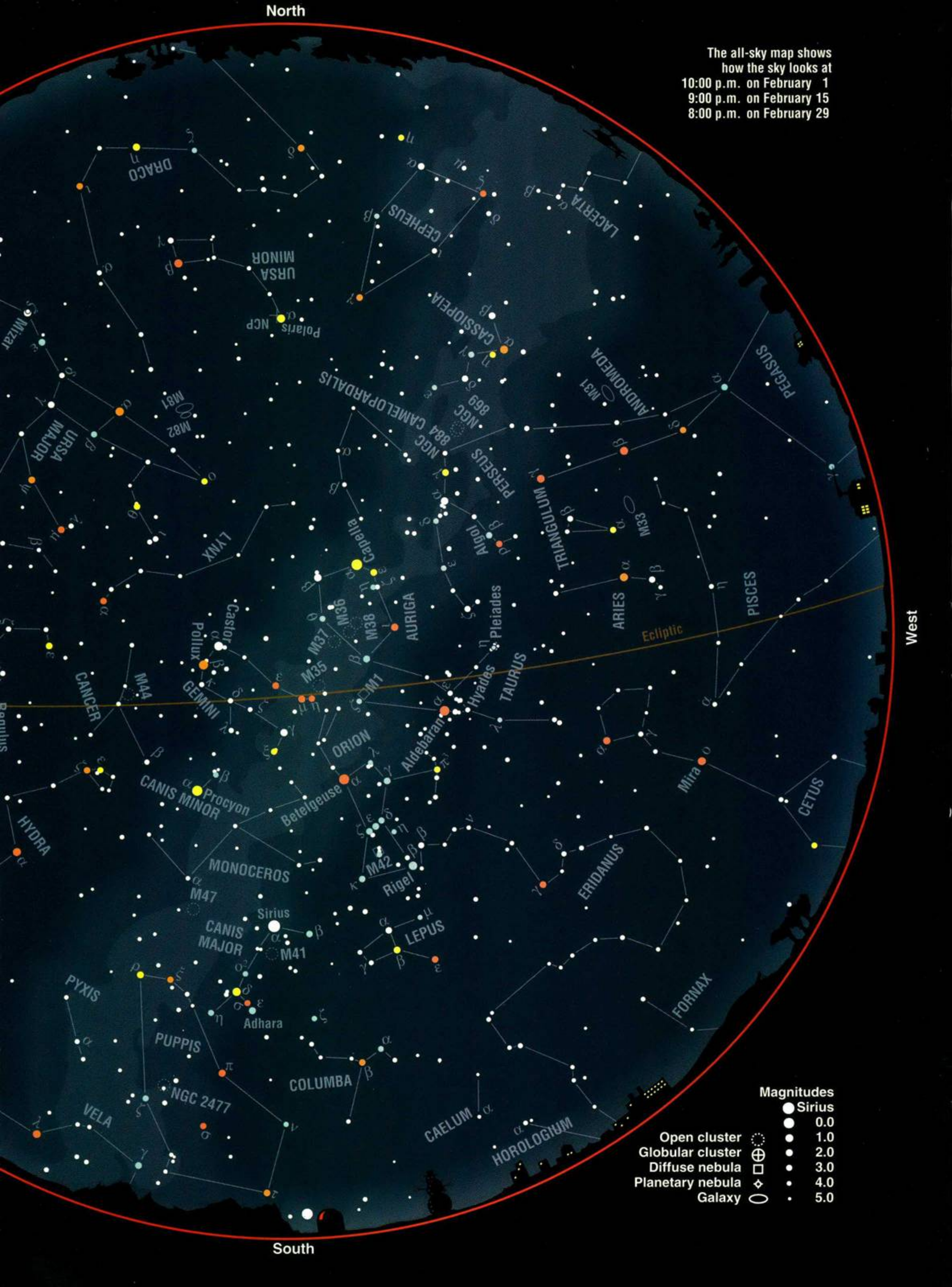


Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29		

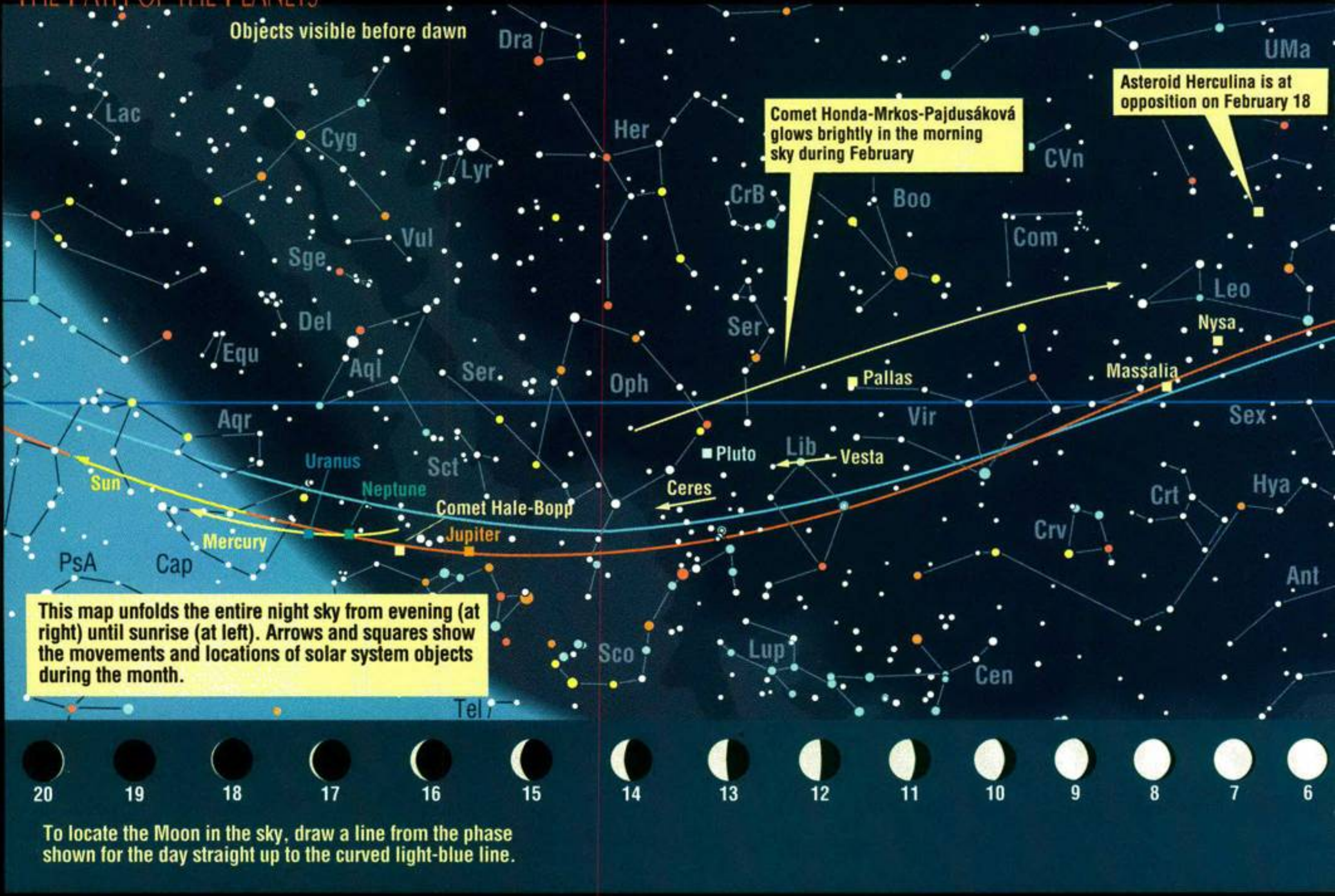


This map portrays the sky at times shown in the upper right corner of the page. Located just outside the map are the four directions: north, south, east, and west. To find stars above your horizon, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows
how the sky looks at
10:00 p.m. on February 1
9:00 p.m. on February 15
8:00 p.m. on February 29


North
West
South
DRACO
CEPHEUS
LACERTA
URSA MINOR
Polaris
NCP
Mizar
CASSIOPEIA
ANDROMEDA
M31
PEGASUS
CAMELOPARDALIS
NGC 869
NGC 884
M81
M82
URSA MAJOR
PERSEUS
TRIANGULUM
M33
Algol
LYNX
Capella
AURIGA
M36
M37
M38
ARIES
PISCES
Pleiades
Ecliptic
Castor
Pollux
CANCER
M44
GEMINI
M35
M1
Hyades
TAURUS
Aldebaran
Regulus
ORION
Mira
CETUS
CANIS MINOR
Procyon
Betelgeuse
HYDRA
M42
Rigel
ERIDANUS
MONOCEROS
M47
Sirius
CANIS MAJOR
M41
LEPUS
FORNAX
PYXIS
Adhara
PUPPIS
COLUMBA
NGC 2477
VELA
CAELUM
HOROLOGIUM
Magnitudes
Sirius
0.0
1.0
2.0
3.0
4.0
5.0
Open cluster
Globular cluster
Diffuse nebula
Planetary nebula
Galaxy

THE PATH OF THE PLANETS


Objects visible before dawn
Dra
Lac
Cyg
Lyr
Her
CrB
Boo
CVn
UMa
Com
Vul
Sge
Del
Equ
Aql
Ser
Ser
Oph
Leo
Nysa
Massalia
Pallas
Vir
Sex
Aqr
Uranus
Neptune
Sct
Pluto
Lib
Vesta
Ceres
Crt
Hya
Sun
Comet Hale-Bopp
Jupiter
Mercury
Crv
Ant
PsA
Cap
Sco
Lup
Cen
Tel
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6

Comet Honda-Mrkos-Pajdusáková glows brightly in the morning sky during February

Asteroid Herculina is at opposition on February 18

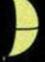
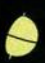
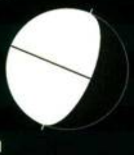
This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

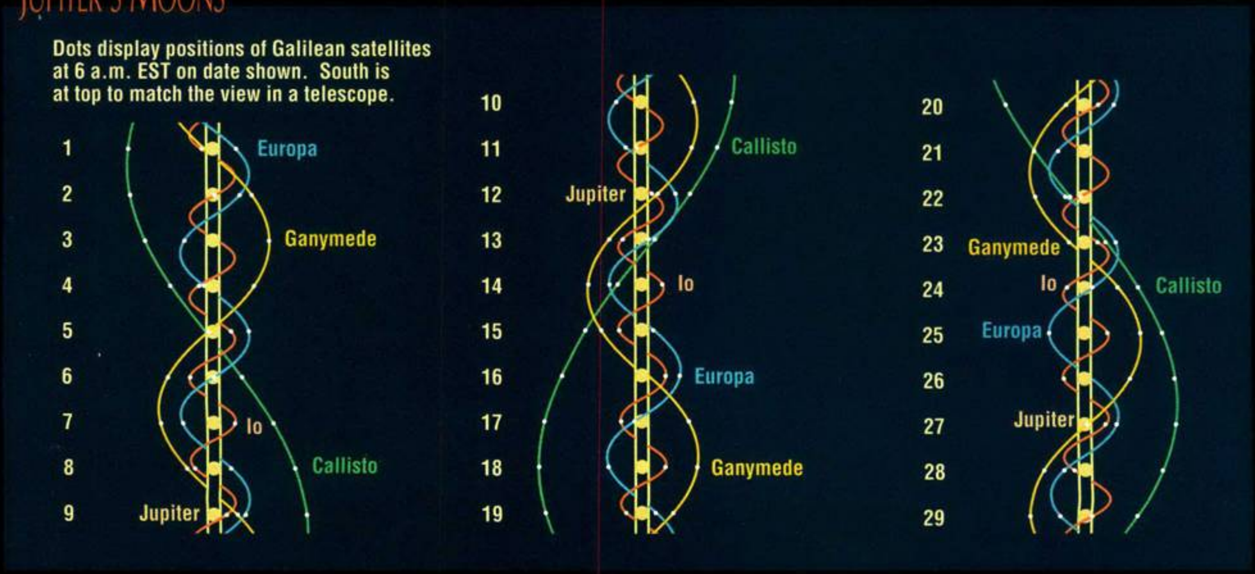
10"

S
W E
N

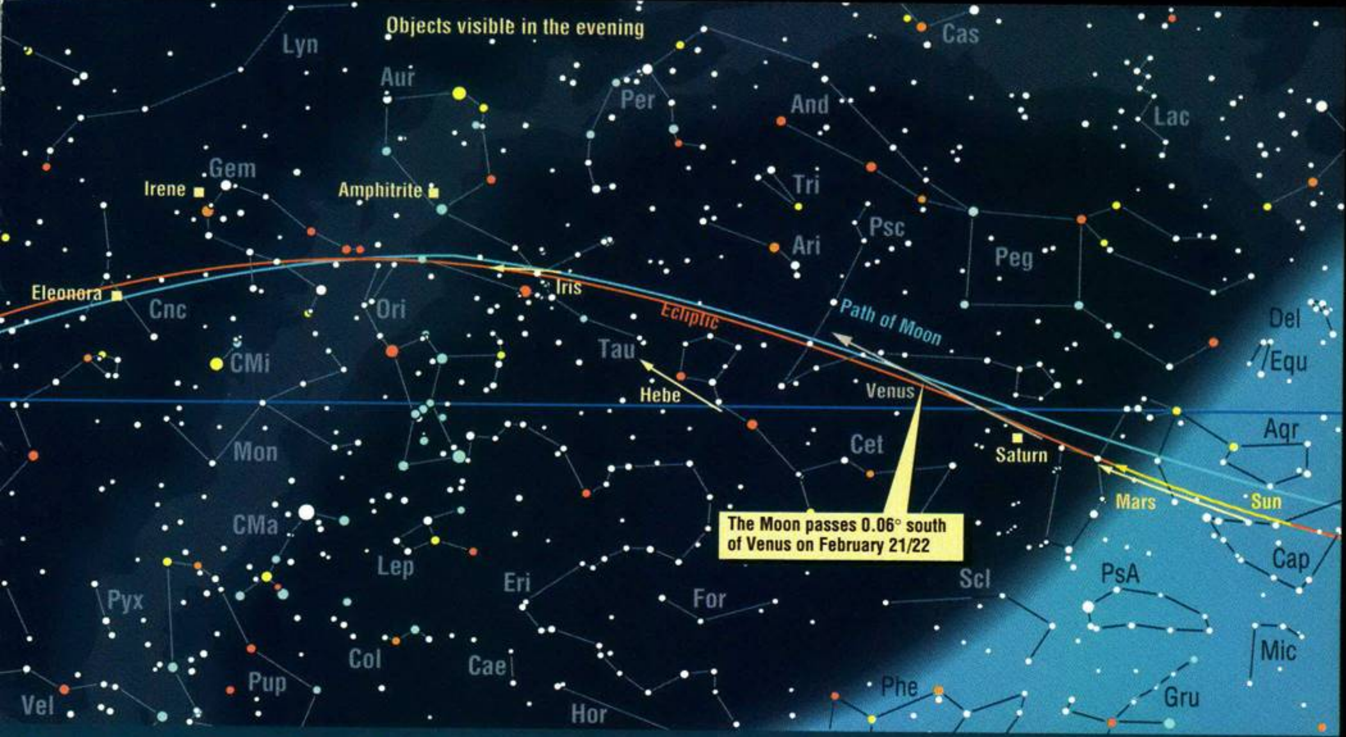
PLANETS	MERCURY	MERCURY	VENUS	MARS	JU
Date	February 1	February 29	February 15	February 15	Feb
Magnitude	0.4	–0.2	–4.1	1.1	
Angular Size	8.4"	5.5"	15.9"	4.0"	
Illumination	35%	82%	71%	100%	
Distance (AU) from Earth	0.797	1.216	1.047	2.365	5
Distance (AU) from Sun	0.391	0.465	0.721	1.382	5
Right Ascension (2000.0)	19h22.2m	21h25.8m	0h26.0m	22h08.6m	18
Declination (2000.0)	–19°35'	–16°55'	2°36'	–12°34'	–

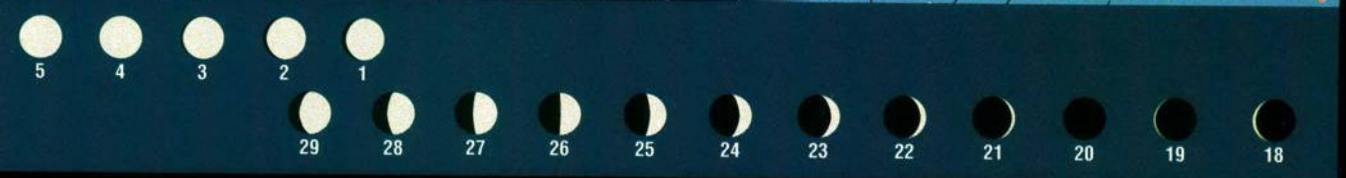
JUPITER'S MOONS


Dots display positions of Galilean satellites at 6 a.m. EST on date shown. South is at top to match the view in a telescope.

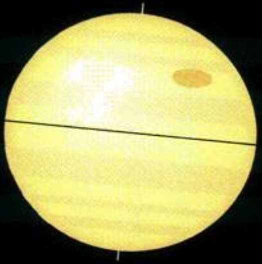
Objects visible in the evening


Lyn
Aur
Per
And
Cas
Lac
Gem
Irene
Amphitrite
Tri
Psc
Ari
Peg
Eleonora
Cnc
Ori
Iris
Ecliptic
Path of Moon
Del
Equ
CMi
Tau
Hebe
Venus
Mon
Cet
Saturn
Aqr
Mars
Sun
CMa
Cap
Lep
Eri
For
Scl
PsA
Pyx
Mic
Col
Cae
Pup
Phe
Gru
Vel
Hor

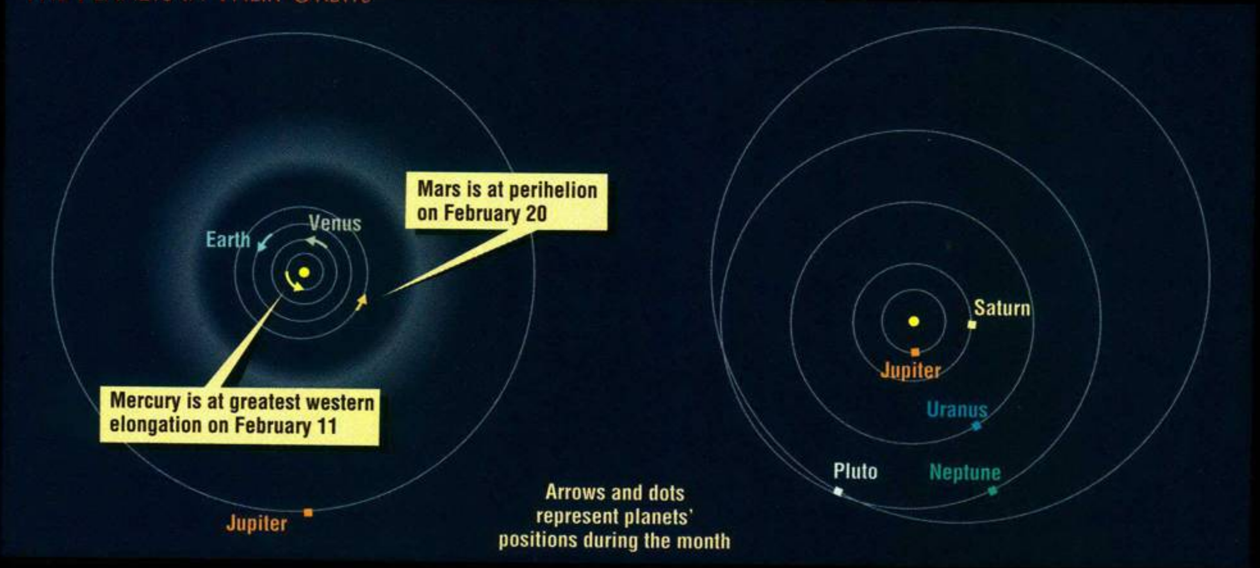
The Moon passes 0.06° south of Venus on February 21/22


5
4
3
2
1
29
28
27
26
25
24
23
22
21
20
19
18

ITER	SATURN	URANUS	NEPTUNE	PLUTO
ary 15	February 15	February 15	February 15	February 15
.9	1.2	5.9	8.0	13.8
.5"	15.9"	3.4"	2.2"	0.1"
0%	100%	100%	100%	100%
884	10.424	20.653	31.022	29.993
254	9.565	19.753	30.164	29.884
9.6m	23h40.0m	20h17.6m	19h53.3m	16h14.1m
°56'	–4°22'	–20°14'	–20°24'	–7°55'



THE PLANETS IN THEIR ORBITS

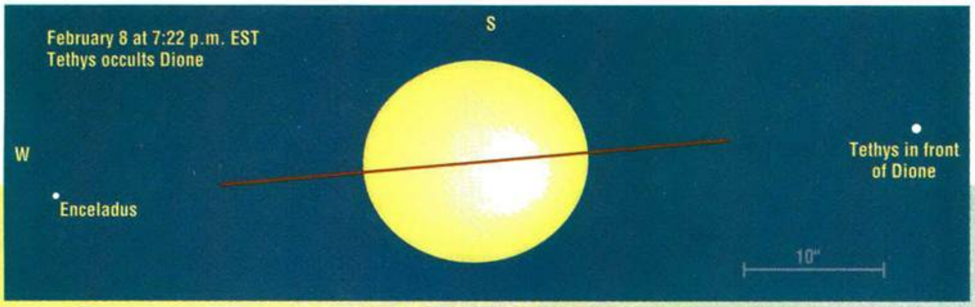

Earth
Venus
Jupiter
Saturn
Jupiter
Uranus
Pluto
Neptune

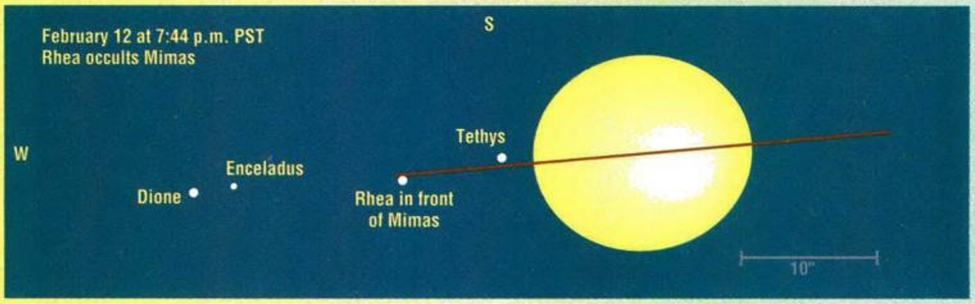
Mars is at perihelion on February 20

Mercury is at greatest western elongation on February 11

Arrows and dots represent planets' positions during the month

Curtain Call for Saturn's Rings





Barely ten days after its conjunction with Venus, rapidly-sinking Saturn hides her rings for the last time until 2009. At precisely 9 p.m. EST on February 11, Saturn's rings appear exactly edge-on to our line of sight. Because the rings are barely one kilometer thick, they disappear every time this viewing geometry occurs. February's disappearance is the final in a series of three witnessed since May 1995.

But there's more to look at this month through a scope than disappearing rings. Ring-plane crossings offer an opportunity to watch Saturn's tiny satellites cast shadows on or cover up one another.

Observers living in eastern North America who are eager for a challenge will want to watch Tethys partially cover Dione for just under three minutes on the evening of February 8, beginning at 7:21 p.m. EST. Because both are slightly dimmer than magnitude 10 and competing with lingering twilight, a keen eye is essential to glimpsing Dione's 37 percent drop in brightness.

While watching this celestial drama unfold, think back to 1684. It was under similar circumstances, near a ring-plane crossing that year, that Italian astronomer Giovanni Cassini discovered these two tiny Moons. Tethys is 1,060 km in diameter, while Dione is 1,120 km across. (By comparison, our Moon is 3,476 kilometers wide.)

Hawaiian observers have a comparatively easier time when they see Saturn's brightest moon, 8.5-magnitude Titan, creep out from behind the planet's shadow over a period of 18 minutes on February 5, beginning at 7:20 p.m. HST. Another mutual event favors West Coast residents, when Rhea passes in front of Mimas on Februray 12 at 7:44 p.m. PST.

Consult the accompanying table to see if these or other events might be visible from your location. Because Saturn sets around 8:30 p.m. local time, it will be low in the sky. With this in mind, view from a site with an unobstructed horizon and steady seeing. Set up on the eastern shore of a lake or on top of a heavily forested hill. Avoid looking over a parking lot, or buildings, which will be radiating heat gathered during the day. — *R.S.*

SATURNIAN SATELLITE EVENTS VISIBLE FROM NORTH AMERICA

Date	Begin Time	End Time	Event	Type of Event	Light Loss	Distance
February 6	5h20.5m	5h38.1m	Saturn eclipses Titan	Reappearance	—	2.0
February 6	23h42.7m	23h50.0m	Dione eclipses Tethys	Partial	36%	4.8
February 9	0h20.7m	0h23.4m	Tethys occults Dione	Partial	37%	4.0
February 10	23h18.8m	23h20.0m	Tethys occults Rhea	Partial	2%	3.2
February 12	23h54.5m	0h26.2m	Dione occults Enceladus	Total	22%	2.5
February 13	0h43.9m	1h46.2m	Dione occults Enceladus	Total	22%	3.1
February 13	3h43.5m	3h45.2m	Rhea occults Mimas	Total	6%	2.3
February 18	1h45.7m	1h48.4m	Enceladus eclipses Tethys	Partial	13%	3.9
February 27	2h09.5m	2h10.5m	Mimas occults Tethys	Partial	6%	2.4

Begin Time: Universal time at beginning of event. (Subtract 5 hours to convert to EST, 6 hours for CST, 7 hours for MST, and 8 hours for PST.) **End Time:** Universal time at end of event. **Event:** The nature of the event and the objects involved. **Type of event:** Whether the event is partial, total, or annular. **Light Loss:** For eclipses — the percent of light lost by the eclipsed satellite at midevent; For occultations — the percent of light lost from the combined light of both satellites at midevent. **Distance:** The apparent distance of the satellite from Saturn's center expressed in Saturnian equatorial radii.

astronomers as opportunities to search for new moons of Saturn. Indeed, many moons have been discovered at times when the rings appeared edge-on to Earth. This most recent ring-plane crossing was no exception.

Last year the Hubble Space Telescope was used to search for new moons of Saturn during the May 24 and August 11 ring-plane crossings. Astronomers are still trying to interpret Hubble's pictures of Saturn, the crispest taken since Voyager 2's flyby in August 1981.

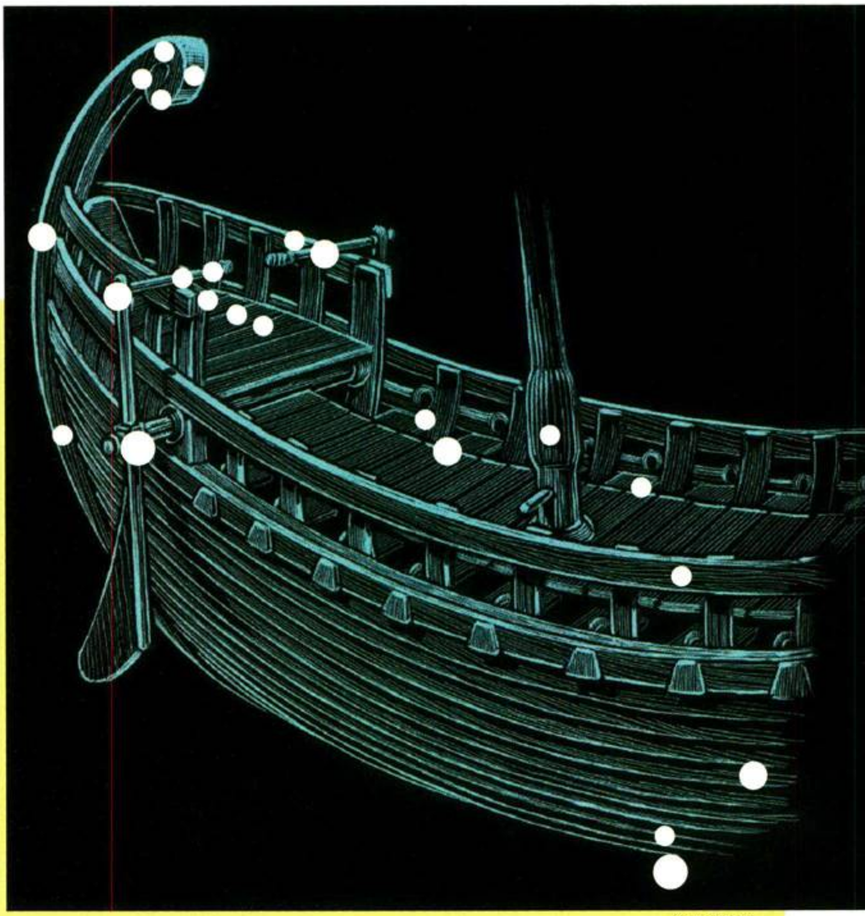
The images suggest that Saturn's ring and satellite system may have evolved since the Voyager flyby. Debris just outside the rings hint that a wayward comet disintegrated when it passed too close to the planet. Vexing speck-like objects could be known moons that have changed orbits. Even as this issue goes to press, astronomers are still arguing about how many moons Saturn has; the number will surely rise higher than 18.

This issue may remained unresolved; the Hubble Space Telescope won't be aimed at Saturn on February 11 because the planet lies too near our line of sight with the Sun.

Earthbound observers also suffer from the ringless planet's proximity to the Sun. Saturn is so low in the western twilight sky this month that a small telescope is likely to show it swimming behind the great thickness of Earth's atmosphere. Despite that, any telescope should reveal Saturn's ringlessness.

All during this month, with each new evening twilight, Saturn sinks closer to the Sun and lower to the western horizon. Take note of Saturn again on February 20, when it lies just below a crescent Moon. By the end of February, Saturn is lost in

The Starry Sky: Canopus and Carina the Keel



Keith Ward

Winter stargazers who find themselves south of latitude 30° should keep an eye out for Canopus, a bright star located too far south on the celestial sphere for most Northern Hemisphere observers. Spotting it has delighted many a snowbird wintering in warmer climes.

The star arcs across our southern sky at nearly the same time each winter as Sirius, the night sky's brightest luminary. But the apparent path of Canopus is lower and smaller than Sirius. From where I live in Texas, Canopus almost looks like a second Sirius, twinkling below its brighter cousin on January and February evenings. I make a habit of looking for it in evening twilight — when it's on the verge of disappearing for another season — around my birthday on March 1.

Canopus has been called the Great Star of the South. It is indeed the second brightest star in the sky, after Canis Major's Sirius. Although Canopus is intrinsically brighter than Sirius, it lies farther away and therefore appears slightly fainter. At a distance of 110 light-years, Canopus is 13 times more distant than Sirius, which is 8.6 light-years from Earth. It also looks fainter than Sirius because Earth's thick atmosphere dims the star's visual appearance for Northern Hemisphere observers. But in the Southern Hemisphere, where the nightly path is much higher in the sky, Canopus truly deserves its reputation as a dazzling star.

The star pattern Canopus anchors is both tough to spot and largely unremarkable for viewers in the Northern Hemisphere. *Carina* is a segment of what was once a magnificent, sprawling constellation called Argo Navis, the legendary ship of Jason and the Argonauts. Modern constellation-makers, the International Astronomical Union, divided Argo into four parts earlier in this century. Mighty Argo became the constellations Carina the Keel, Vela the Sail, Puppis the Stern, and Pyxis the Mariner's Compass.

A ship's keel is a long piece of timber or steel that runs a vessel's length, and largely determines the ship's stability or sea-worthiness. From the word we have derived the expression "on an even keel" to mean "to move along in a calm and unperturbed way." We also have "keel over" to mean "turn over," or "turn upside-down."

In an interesting instance where language, myth, and modern science intersect, latter-day celestial navigators use Carina's brightest star to keep spacecraft on a steady course as they move through the solar system. Canopus serves this purpose not only because of brightness, but also because its position lies at nearly a right angle to the plane of our solar system. Thus, in our time, "acquiring Canopus" with a spacecraft's sensors has become a routine part of planetary exploration.

Can you acquire Canopus? Look outside on an any evening this during February when Canis Major's Sirius is at its highest in the south. Well below the Dog Star might be Carina and Canopus riding low along your southern horizon. — *Deborah Byrd*

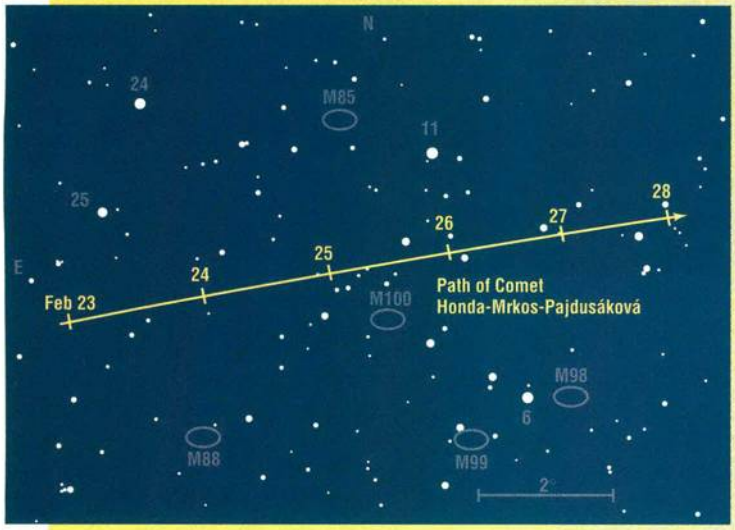
Of Comets That Leap and Crawl

Comet Honda-Mrkos-Padjusáková opens leap month in the midst of a sprint through the morning sky. During February's 29 days, the comet covers a whopping 75° of sky along a path that starts just west of Ophiuchus in Serpens Caput, continues through Virgo, and ends up north and east of Denebola, the "tail star" of Leo. This breakneck speed is primarily due to a closer-than-usual approach to Earth. On February 5 the comet passes some 0.171 astronomical units, or 25 million kilometers, from our planet, shining at around magnitude 7.

H-M-P's close pass to Earth provides a rare opportunity to view its nucleus at high power through a telescope. Keen-eyed observers should see a lot of interesting fan-shaped structure close to its center. This structure is caused by jets of gas blasting off localized areas of the comet's icy surface that are warmed by the Sun's rays.

On top of these fascinating telescopic sights, H-M-P's swift journey carries it near many Virgo Cluster galaxies, affording both astrophotographer and visual observer alike the chance to track its motion and note any interesting close passes. On the Moonless morning of February 25, the comet lies nestled in southern Coma Berenices near the magnitude-9.4 spiral galaxy M100 and nearby galaxies NGC 4383 (magnitude 11.6), NGC 4350 (11.1), and NGC 4340 (11.0). ASTRONOMY welcomes all photos and drawings of H-M-P's brush with these galaxies.

Meanwhile, far below and to the east, in the western regions of Sagittarius, lies Comet Hale-Bopp, which continues its slow crawl out of morning twilight. What could next year's brightest comet, not to mention the brightest one in 20 years, presently glows at around magnitude 10.5, just under the Archer's "teaspoon" asterism. Later in February, the comet draws to within 10° of Barnard's Galaxy (NGC 6822), a sprawling (10.2' by 9.5') dwarf galaxy in Sagittarius with a magnitude of 8.5. — *R.S.*



COORDINATES FOR COMET HONDA-MRKOS-PAJDUSÁKOVÁ

Date*	R.A. (2000)	Dec.
February 1	16h52.4m	–4°35'
February 5	15h54.7m	0°42'
February 9	14h58.7m	5°46'
February 13	14h08.9m	9°56'
February 17	13h27.0m	12°58'
February 21	12h53.0m	15°02'
February 25	12h25.8m	16°22'
February 29	12h04.1m	17°11'

* Positions given for 5 a.m. EST

Herculina: A Giant in the Dark

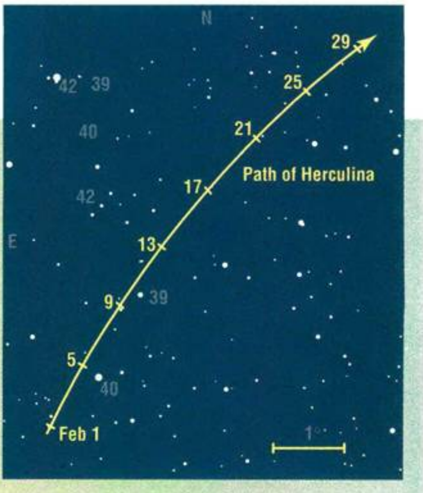
Lurking under the paws of Leo Minor during February is this month's asteroid target, the 532nd to be discovered: Herculina. This 231-kilometer-diameter chunk of rock is one of the larger asteroids known and is high on a list of asteroids ranked by albedo, or ability to reflect the Sun's light. Herculina's albedo approaches 0.1, which is greater that the Moon's 0.07. Despite this apparent claim to brightness, Herculina only reflects less than 10 percent of the light that reaches it. That, coupled with its 780 million kilometer-plus distance, combines to make it glow at around magnitude 9 all during the month of February.

Use the finder map to track Herculina as it takes the entire month to meander through Leo Minor. To confirm the asteroid's subtle presence, make a drawing of all stars visible in a telescope's field of view on one night, and then make another drawing of the same field on the next clear night. The one "star" that moves is Herculina drifting through interplanetary space as it completes a 4.6-year circuit around the Sun. — *R.S.*

COORDINATES FOR 532 HERCULINA

Date	R.A. (2000)	Dec.	Mag.
February 1	10h46.1m	25°37'	9.0
February 5	10h44.1m	26°30'	9.0
February 9	10h41.7m	27°23'	8.9
February 13	10h39.0m	28°14'	8.9
February 17	10h36.0m	29°02'	8.8
February 21	10h32.8m	29°49'	8.9
February 25	10h29.5m	30°29'	8.9
February 29	10h26.3m	31°06'	8.9

* Positions for 11 p.m. EST



the Sun's glare. When it returns to the morning sky in April, its rings will begin opening again.

Quite the opposite from Saturn's march into sunset is the steady climb of Venus out of evening twilight. This planet's greatest elongation — when it has reached the end of its imaginary tether with respect to the Sun — happens on April 1. Venus also gets a little brighter between now and then. It will be a beautiful sight in the evening sky throughout this winter and spring.

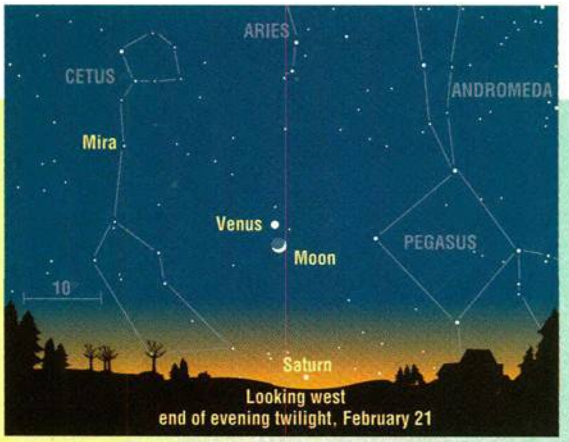
Be sure to look for Venus this month when it is near the Moon on the night of February 21. An occultation is visible from Indonesia, western and northern Australia, and the Pacific Ocean.

After Venus sets more than two hours after the Sun, planet enthusiasts have to wait until morning to get their fill of action. At the beginning of February **Jupiter** makes a morning comeback in the southeast after passing behind the Sun last month. You'll have no trouble recognizing the planet, for at magnitude –1.9, it outshines everything else in the eastern predawn sky — until the Moon sweeps past on the morning of February 15.

Jupiter is now in front of the constellation Sagittarius, but its old friend Antares, the brightest star in neighboring Scorpius, is still located near it in the sky. Antares lies above to the right of the planet in the east before dawn this month. Jupiter will get higher in the sky as this month passes. A telescope turned in its direction reveals a disk spanning 33.5", red-and-tan cloud bands, and at least four orbiting moons.

Mercury is also up before the Sun this month. The solar system's innermost planet appears below and to the left of Jupiter in the predawn sky. It shines at magnitude 0.4 when the month begins and brightens to magnitude 0.0 by the time of its greatest elongation on February 11. That winter morning apparition sees

Venus Rides a Crescent Moon



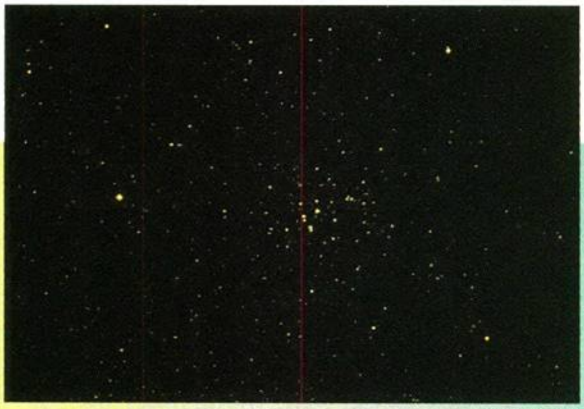
On the night of February 25 the Moon passes just south of Venus in the evening sky. For eastern North America, the separation is about 1°, or twice the apparent size of the Moon. West Coast Observers see a separation of about 0.5°, while observers in Alaska, Hawaii, and the Central Pacific witness a closest approach of approximately 0.1°.

As with the February 1 conjunction of Venus and Saturn, this event has little scientific relevance. However, it does allow us to compare the icy-white light of Venus to the relatively dusty color of our Moon. Oftentimes the Moon looks brownish, which is certainly not a color we perceive when there is no comparison object nearby. What color do you see?

Another feature to note during this conjunction involves phases. The Moon's phase is a waxing crescent, while a look through a scope shows a gibbous for Venus. This apparent disparity is easily explained when you consider that the Moon is on Earth's side of the Sun, while Venus is on the other side. Hence, we can't see much of it's unlit portion. — *R.S.*

First Views:

M44's Little Cloud of Bees



Mace Hooley

A sign of spring this year for people living in the southwest is the continued expansion of "Africanized honey bees" into the U.S. from Mexico. But there's another, less sinister swarm of bees that serve as gentler harbingers of spring. These "bees" are of the celestial variety, and make up one of the most beautiful open clusters in the sky: M44, also know as the Praesepe, Latin for beehive.

M44 is easy to find, appearing as cloudy patch of light about twice the size of the Full Moon in the constellation of Cancer the Crab. Since Cancer is such a faint constellation to begin with, look for M44 as a cloudy area about midway between Leo and Gemini.

The reason the Beehive looks cloudy is that its brightest star, Epsilon (ε) Cancri, glows faintly at magnitude 6.3. Meanwhile, 14 other members in the cluster have magnitudes brighter than 7.5. Many observers can't see a star of magnitude 6.3 without optical aid. So, most people perceive the light from all the stars in the cluster as a hazy patch of light whose equivalent magnitude is 3.1.

The fuzzy, naked-eye visibility of the Beehive Cluster has served as a weather forecasting tool since ancient times. The Greeks held that if Praesepe was obscured by mist, bad weather would usually follow. We now know that cirrus clouds obscure objects like the Beehive and are, indeed, harbingers of rain.

It wasn't until Galileo first observed the Beehive with a telescope in 1610 that the cluster's true nature was discovered. Even Galileo's crude telescope showed more than 30 bees in the hive. Present-day studies show there are more than 300 members. We have also deduced that the Beehive is 520 light-years away and about a dozen light-years across. That places it as one of the nearest open clusters to Earth.

Because of its proximity to Earth, the Beehive cluster is magnificent in binoculars and looks even better in a low-power telescope having a field of 2 to 3°. It's also one of the easiest clusters to photograph with moderate telephoto lenses. — *R.S.*

Mercury 26° west of the Sun on Earth's sky dome.

This is not a particularly outstanding apparition of Mercury. The ecliptic — or path of the Sun, Moon and planets — makes a rather shallow angle with the eastern horizon before dawn. Still the planet should be easy to spot if you know where to look.

A good time for this is when the waning crescent Moon passes through Mercury's region of the sky. Try looking below the Moon on the morning of February 16, and to the right of the Moon on the morning of February 17. Use binoculars if you need them.

Mercury is also interesting to watch through a telescope during February. The planet passed between Earth and the Sun last month, so early this month it shines as a crescent world in our predawn sky. The crescent Mercury will wax, or get larger, as the month passes.

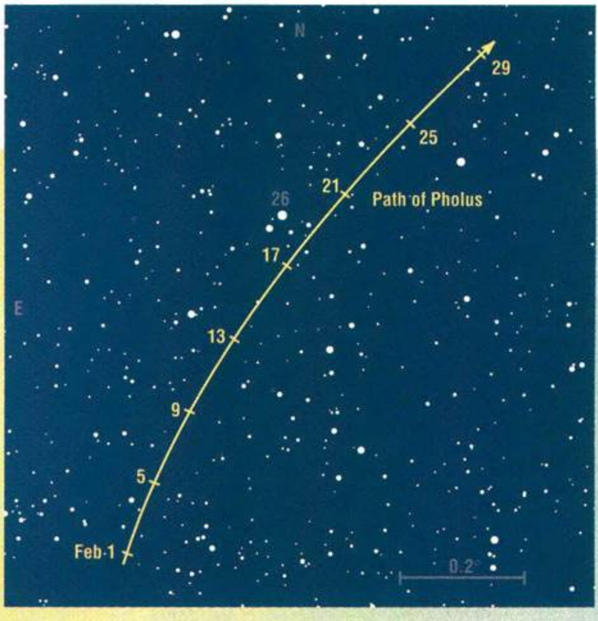
Rounding out the predawn planet parade is **Pluto**, the outpost planet in our Sun's family. It's up in the wee hours when this month begins, in front of the constellation Scorpius. It lies in the south an hour or so before dawn. Pluto rises earlier each morning and finally reach opposition — when it's conveniently placed for evening viewing with a telescope — in May.

Outer gas giants **Uranus** and **Neptune** are up before sunrise but too low in the sky to be of much interest telescopically. Neptune has a conjunction with Mercury on February 11, and Uranus is in conjunction with Mercury on February 16.

Finally, **Mars**, on its way to a March conjunction, **is too close to** the Sun to see during February. The Red Planet won't be of interest to observers until May, when it returns to the predawn sky. ☐

Deborah Byrd writes the Earth and Sky radio series. Rick Shaffer is a science writer living in Arizona.

Observer's Challenge: 5145 Pholus



COORDINATES FOR 5145 PHOLUS*

Date	R.A. (2000)	Dec.	Mag.
February 1	12h40.8m	20°12'	18.0
February 5	12h40.5m	20°23'	17.9
February 9	12h40.1m	20°34'	17.9
February 13	12h39.6m	20°45'	17.9
February 17	12h39.1m	20°55'	17.9
February 21	12h38.4m	21°07'	17.9
February 25	12h37.7m	21°18'	17.9
February 29	12h37.0m	21°28'	17.8

* Positions for 5 a.m. EST

Trans-Neptunian objects are icy asteroids that orbit in the Kuiper Belt beyond the orbit of Pluto. Occasionally, one of these objects is kicked into a new orbit inside the orbits of the outer planets, becoming what are called Centaur objects.

The most famous of these is 2060 Chiron (see "Tracking a Distant Comet World" on page 80), a large object that has some characteristics of both an asteroid and a comet. It was discovered in 1977 by Charles Kowal.

Once its orbit was known, "Object Kowal" was assigned a number, as is done with all asteroids. Mr. Kowal chose the name Chiron for his asteroid.

However, in 1988, routine observations of Chiron revealed that it had nearly doubled in brightness. Further observations revealed a cometary coma. All this was occurring at a distance of 11.2 astronomical units, beyond Saturn. So while Chiron has an asteroid's orbit, it also has volatile material on its surface that sublimes into a gaseous coma.

This month's observer's challenge is another Centaur object, 5145 Pholus, only recently discovered by astronomers looking for members of the enigmatic Kuiper Belt (see "The Remarkable Odyssey of Jane Luu" on page 46). Pholus brightens this month to 17.8, making it too dim to be seen visually by all but the very largest amateur telescopes. Scopes in the 25- to 40-inch range might allow those with keen vision to identify it.

That said, this month's challenge is therefore more photographic than visual. CCD cameras working with telescopes as small as 8 inches routinely push limiting magnitudes well beyond the brightness of Pholus. So on paper at least, getting an image of this Centaur object would seem to be a fairly simple task. Take an exposure of several minutes, and then look for the "star" that's trailed on the image.

So far, so good. But, here's the inevitable catch. Pholus moves across the sky only 0.01° each day. This tiny angular movement is due to the length of Pholus' orbit, 91.6 years. So, if you use a telescope with a focal length of 2-meters (say, an 8-inch SCT), and expose for an hour, the image of Pholus would only "trail" across 60 percent the width of one CCD pixel. (Your guiding and the seeing should be so good!)

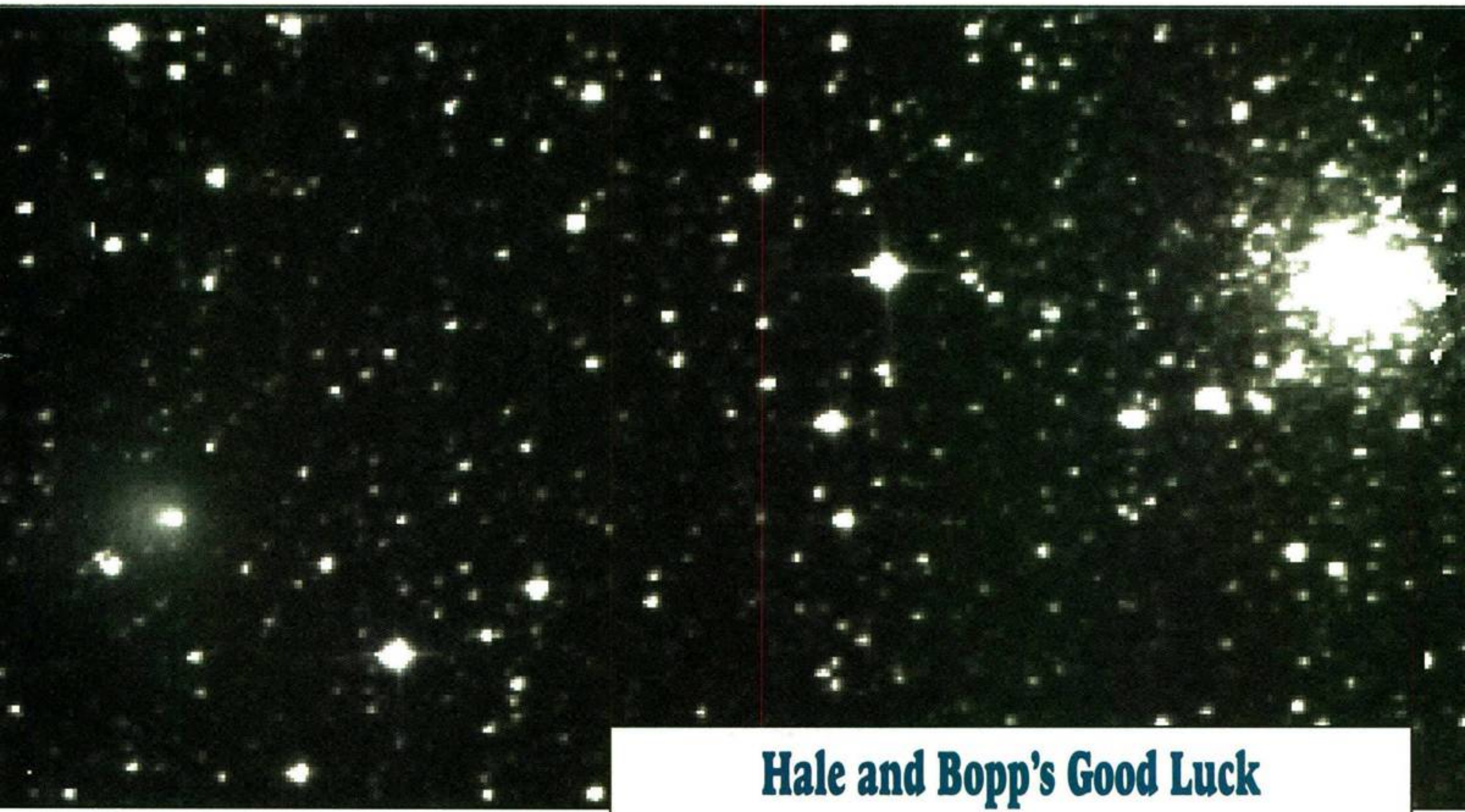
With that in mind, there are only two ways to confirm the elusive presence of Pholus. One is to compare side-by-side images of Pholus taken a few days apart. Account for each star image until coming across one that lacks a counterpart on the other image. If this seems too tedious, make use of a "blink" feature found on some image-processing software packages. The blink routine compares two images digitally, and outputs the difference. Unless there is a new object in the CCD frame (a comet or distant nova, for instance), the one that "blinks" is Pholus.

ASTRONOMY would like to see the results of your attempt to identify this tiny Centaur object. — *R.S.*

HERE COMES HALE-BOPP

A promising new comet brings hope to backyard astronomers around the world.

by David J. Eicher



Wayne Johnson and OCA

Comet Hale-Bopp and Globular Cluster M70

Hale and Bopp's Good Luck

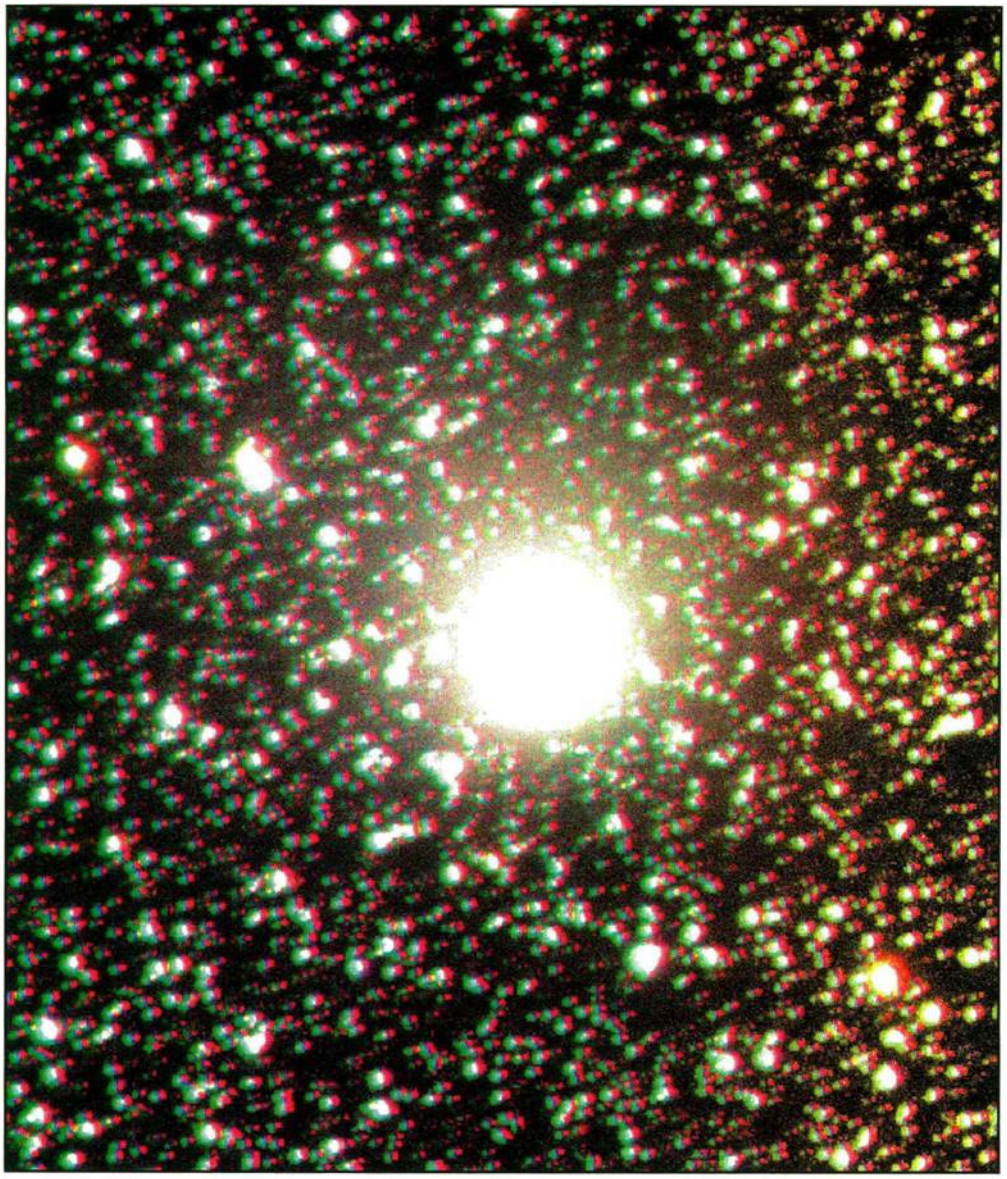
"I love the irony," says Alan Hale of his discovery of Comet Hale-Bopp (left in photo). "I've spent over 400 hours of my life looking for comets and haven't found anything, and now, suddenly, when I'm not looking for one, I get one dumped into my lap." Hale, a backyard observer from Cloudcroft, New Mexico, was observing the globular cluster M70 (right in photo) in Sagittarius on July 23, 1995. "I saw a fuzzy object in the field, and immediately suspected a comet," he says.

The second discoverer, Thomas Bopp, was observing deep-sky objects at a dark site near Stanfield, Arizona. Bopp was watching M70 drift across the field when "a slight glow appeared on the western edge of the field," he says. By the following day astronomers had given the object, provisionally designated C/1995 O1, a name: Comet Hale-Bopp.

We've seen it before. A new comet looms large far away in the blackness of the solar system. Astronomers find it out beyond the orbit of Jupiter, some 7 astronomical units away. It's large, bright, and promises to put on a spectacular show as it approaches the Sun months later. A number of astronomers feel it will be the "comet of the century." A buzz erupts throughout the astronomy clubs and communities of the world.

It's not only happening now, with newly discovered Comet Hale-Bopp. It happened once already, in 1973. Back then, Comet Kohoutek promised to mesmerize the general public with a tail dozens of degrees long and a total magnitude approaching that of Venus. Instead, Kohoutek fizzled. Ever since, comet astronomers have taken the heat. This time, the astronomers are determined that they won't get fooled again.

Caution is the key word for Hale-Bopp. Now moving in toward the Sun and Earth, it promises to be the brightest comet to grace Earth's sky in 20 years. Hale-Bopp is gradually brightening each day and — if this trend continues — will become a major



Neil Trentham, University of Hawaii

event for astronomers and the general public over the next 20 months. Now visible in small telescopes, the comet will grow to visibility in binoculars by March 1996. By August 1996 the comet will be visible with the naked eye.

Then, after conjunction with the Sun and at its brightest in March and April 1997, the comet will be a spectacle, a spray of gray-green light glowing in the northwestern sky after sunset.

Hale-Bopp was merely a faint fuzz of milky light when it was discovered independently on July 23, 1995, by backyard astronomers Alan Hale in New Mexico and Thomas Bopp in Arizona.

Both were observing a globular star cluster, M70, in the constellation Sagittarius when they spied the fuzzy comet, located close by. Within two weeks astronomers had calculated a preliminary orbit for the comet and knew that it would be significantly bright in Earth's skies over the next year-and-a-half.

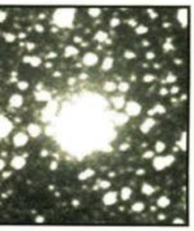
Astronomers already know of some unusual aspects of Comet Hale-Bopp. It is much larger than most comets that swing in toward the Sun. The envelope of dust surrounding Hale-Bopp stretches over 2.5 million kilometers, so the comet has a volume larger than the Sun. The nucleus itself, the icy ball slowly giving up its gases, may span several dozens of kilometers.

Scientists at major observatories have already imaged luminous jets of material squirting from the comet's nucleus as its icy surface cracks and spews warm gases from inside. The comet is now 630 million miles from the Sun and will be a mere 85 million miles distant at its closest approach on April 2, 1997. The comet's huge size and activity at such a large distance suggest it will pack a full punch when it enters the inner solar system, warms further, and forms a long tail a year from now.

For more than a year-and-a-half, observing Comet Hale-Bopp will be a lasting pleasure regardless of the type of telescope used. The comet's visibility divides into five major periods. These are March–July 1996; August–November 1996;

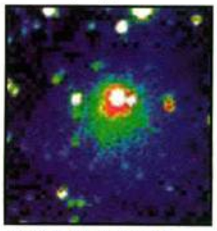
Watching the Comet Change

July 26, 1995



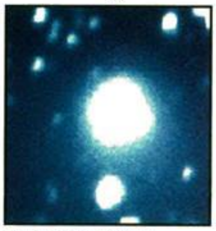
ordon Garradd, Siding
pring Observatory

July 30



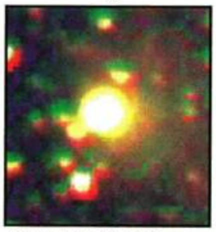
Eleanor Helin, Palomar Observatory

Aug. 2



Dave Harvey, Steward Observatory

Aug. 6



Dave Harvey, Steward Observatory

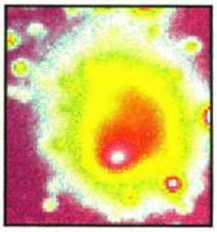
Aug. 18

Paul Francis, University of Melbourne

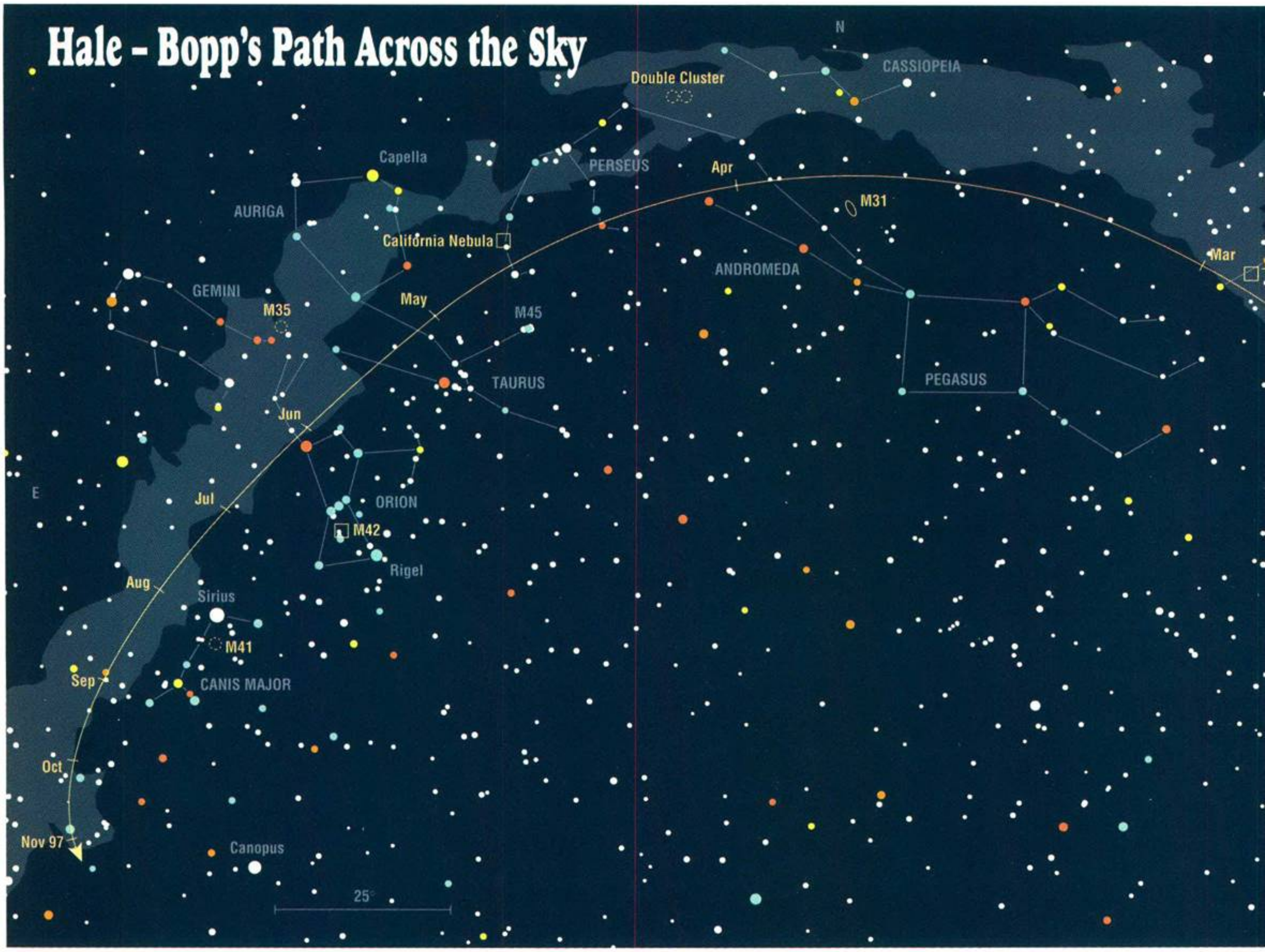
Aug. 28

Jun Chen, University of Hawaii

Sept. 1



Mats Dahlgren, ESO


Hale - Bopp's Path Across the Sky

December 1996–January 1997; February–March 1997; and late March–April 1997. Each period represents a milestone in the comet's brightness and appearance. For each period, we'll survey the possibilities for Hale-Bopp, how bright it will be, the objects it will pass, and the best times for observing the comet unhindered by the Moon.

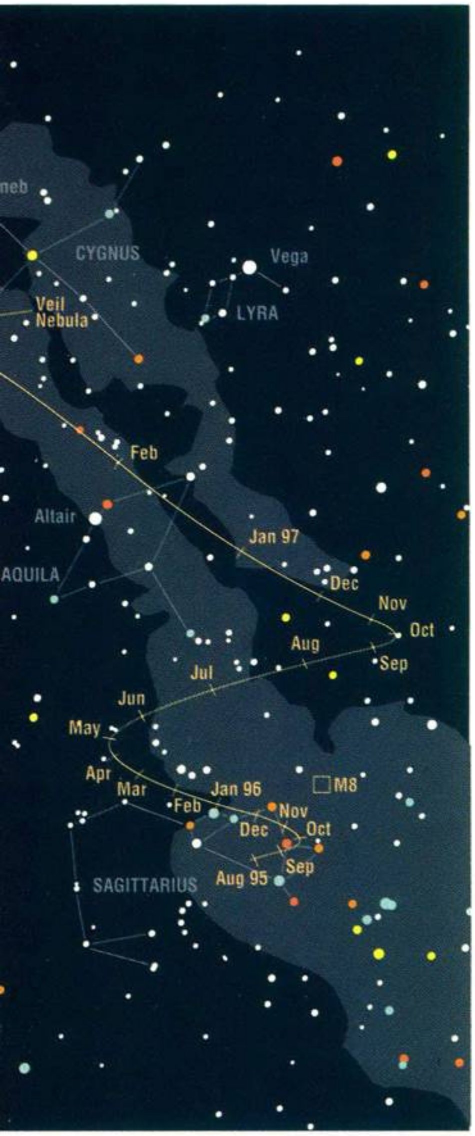
During **February** and **March 1996**, the comet moves slowly through Sagittarius and brightens to binocular visibility. Hale-Bopp begins the period glowing at magnitude 9.5 and reaches magnitude 8.5 by the end of March. The comet is visible beginning in late February, rising a small distance above the horizon in the predawn sky. By the end of March the comet rises high enough to be visible without difficulty before dawn. The Moon does not interfere with seeing the comet in February; in March the best moonless nights come early and late in the month. During February and March the comet's slow movement carries it between Jupiter and Neptune, both found in Sagittarius.

In **April** and **May 1996** the opportunities for observing Hale-Bopp widen. By now the comet rises in the wee hours of the morning and is well-placed, high in the sky, as dawn breaks. Hale-Bopp still resides in Sagittarius and inches slowly along its path. In mid and late May the comet moves west of the faint galaxy NGC 6822, known as Barnard's Galaxy, a faint specter of the Local Group.

But for most of the two-month period the comet is alone, an object brightening from magnitude 8.3 to nearly 7, becoming a respectable sight in a good pair of binoculars. The best opportunities for observing Hale-Bopp under a dark sky come during the first couple of days and last two weeks of April and the final two weeks of May.

Come **June** and **July 1996**, as summer warms the Northern Hemisphere, Hale-Bopp begins making its case to be remembered. Still lodged in Sagittarius, the comet rises around midnight and remains visible throughout the rest of the night. The second and third weeks of June and July offer the best opportunities for avoiding the wash of moonlight over the comet's fragile light.

The comet brightens from magnitude 7.0 on June 1 to brighter than 6th magnitude at the end of July, bringing it into naked-eye range for vigilant observers in a very dark sky. By this time the comet should sport a visible tail *that will impress telescopic* observers. As if to entice backyard astronomers further, Hale-Bopp



begins a zigzag dance between the rich area of Milky Way marked by the Omega and Eagle nebulae and the lustrous glow of the Scutum starcloud.

The second great act of Hale-Bopp's show starts splendidly. In **August** and **September 1996** the comet is visible with the naked eye under a very dark sky, even to those without extensive observing experience. Hale-Bopp now hangs in view from the evening hours until an hour or two after midnight. Having moved out of Scutum, the comet slowly climbs through Serpens Cauda and into Ophiuchus.

On August 5 the comet slides between the globular clusters NGC 6517 and NGC 6539, separated by less than 2°, and briefly kisses the 6th-magnitude double star Tau (τ) Ophiuchi. During August and September the comet

Where to Find Comet Hale-Bopp

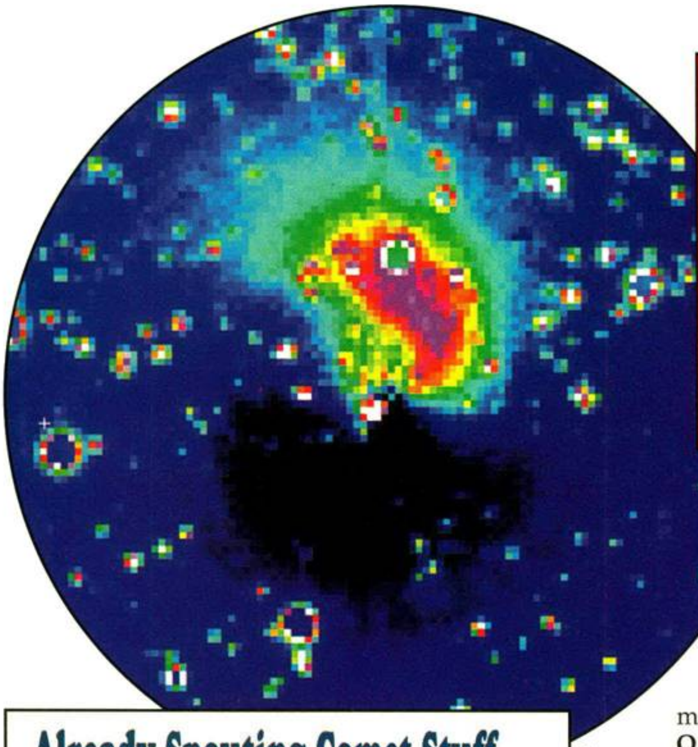
Date	R.A. (2000) Dec.	Mag.	Constellation
1996			
Jan. 15	19h02.4m –24°25'	9.7	Sagittarius
Feb. 1	19h13.4m –23°29'	9.5	Sagittarius
Feb. 15	19h22.0m –22°41'	9.2	Sagittarius
Mar. 1	19h30.4m –21°44'	8.9	Sagittarius
Mar. 15	19h37.0m –20°48'	8.7	Sagittarius
Apr. 1	19h42.7m –19°37'	8.3	Sagittarius
Apr. 15	19h45.0m –18°35'	8.0	Sagittarius
May 1	19h44.1m –17°21'	7.7	Sagittarius
May 15	19h39.5m –16°12'	7.3	Sagittarius
June 1	19h28.6m –14°44'	7.0	Sagittarius
June 15	19h14.9m –13°26'	6.6	Sagittarius
July 1	18h54.7m –11°53'	6.3	Scutum
July 15	18h34.7m –10°29'	6.0	Scutum
Aug. 1	18h10.7m –8°52'	5.7	Serpens Cauda
Aug. 15	17h53.7m –7°42'	5.5	Ophiuchus
Sept. 1	17h38.9m –6°32'	5.4	Ophiuchus
Sept. 15	17h31.9m –5°46'	5.2	Ophiuchus
Oct. 1	7h29.6m –4°59'	5.0	Ophiuchus
Oct. 15	17h32.0m –4°17'	4.8	Ophiuchus
Nov. 1	17h39.8m –3°18'	4.5	Ophiuchus
Nov. 15	17h49.5m –2°14'	4.1	Ophiuchus
Dec. 1	18h04.1m –0°35'	3.7	Serpens Cauda
Dec. 15	18h19.7m 1°24'	3.2	Ophiuchus
1997			
Jan. 1	18h42.5m 4°48'	2.6	Serpens Cauda
Jan. 15	19h05.3m 8°45'	1.9	Aquila
Feb. 1	19h40.6m 15°32'	0.9	Aquila
Feb. 15	20h21.1m 23°23'	0.2	Vulpecula
Mar. 1	21h22.4m 33°22'	–0.9	Cygnus
Mar. 15	23h02.9m 43°01'	–1.4	Andromeda
Apr. 1	1h48.4m 44°29'	–1.7	Andromeda
Apr. 15	3h31.9m 36°32'	–1.5	Perseus
May 1	4h41.1m 25°55'	–0.5	Taurus
May 15	5h19.8m 17°59'	0.2	Taurus
June 1	5h54.5m 10°01'	1.2	Orion

Along with the date, this table provides the comet's position in **right ascension** and **declination** (epoch 2000.0), equivalent to longitude and latitude on the sky. The **magnitude** is a measure of the comet's brightness: the faintest stars visible to the naked eye glow at about magnitude 6, the brightest at about magnitude –1.5. The brighter the comet gets, then, the smaller the number. The **constellation** column shows in which star group the comet appears.

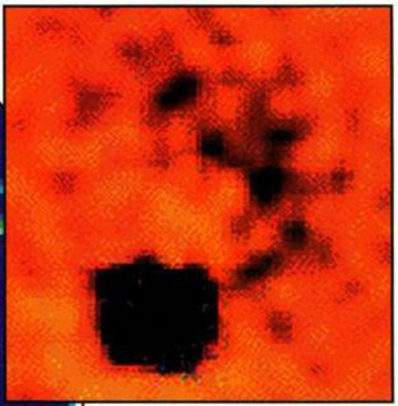
Orbital Elements for Hale-Bopp

Epoch March 13.0, 1997

Perihelion Time (*T*)	April 1.64155, 1997
Perihelion Distance (*q*)	0.9130230 AU
Eccentricity (*e*)	0.9944413
Argument of Perihelion (ω)	130.66776°
Longitude of ascending node (Ω)	282.47292°
Inclination (*i*)	89.41422°



Emilio Molinari and Hans Kaeufl, ESO



Mark Kidger, Teide Observatory

brightens from magnitude 5.7 to nearly 5th magnitude. The best windows for dark-sky viewing come in the first weeks of both months.

October and **November 1996** offer new chances to spy the comet. Around October 1, the comet takes a sharp northward turn, climbing in declination rapidly and accelerating in its daily movement. As the autumn air casts a chill over the ground, comet enthusiasts will no doubt stick with their emerging giant. Spending this period in Ophiuchus before moving back into Serpens Cauda, Hale-Bopp brightens to nearly 4th magnitude by the end of November. It is now an evening object, visible at dusk until late evening in October and from nightfall to mid-evening in November. The moonless windows occur during the first two-and-a-half weeks of October and during the first two weeks and last week of November. During this period the naked-eye comet passes near three globular star clusters. On October 1 the comet skims NGC 6366. During the final four days of the month the comet brushes south of M14 (NGC 6402). On November 29, Hale-Bopp moves just south of NGC 6535.

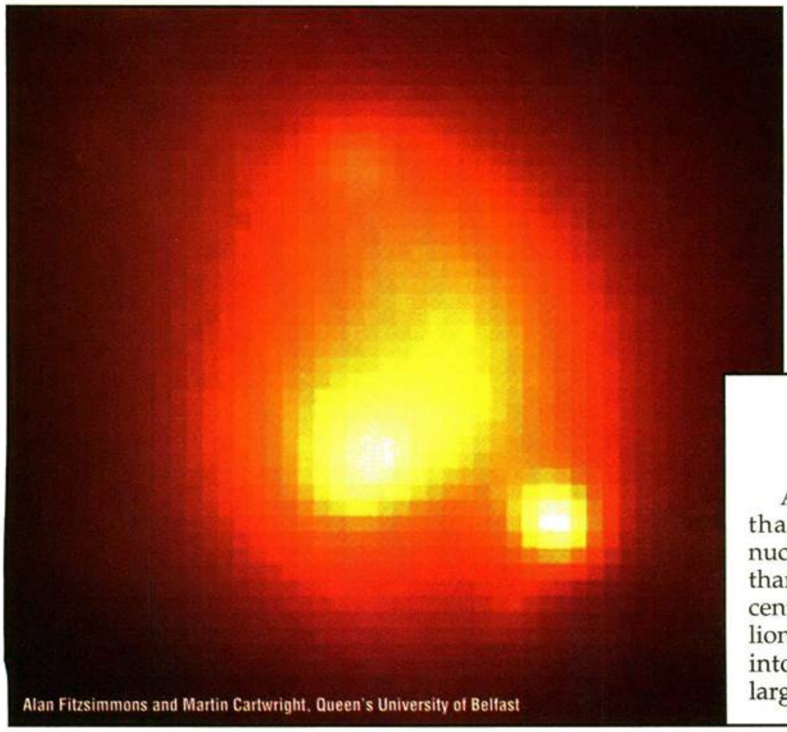
And then the hiatus. In **December 1996** and **January 1997** the Sun and comet move too close together in our sky to permit seeing Hale-Bopp, except with great difficulty. The comet spends this time moving from Serpens Cauda back into Ophiuchus, from Ophiuchus back into Serpens Cauda, and on into Aquila. Some keen-eyed observers might spy the 3rd-magnitude fuzzball and its tail very low in the western evening sky, particularly in the first two weeks of December before moonlight bleaches the sky.

The comet's passage near the whopper open cluster IC 4756 goes virtually unseen. By January the comet is definitely very hard to see, though its total magnitude equals that of a 1st-magnitude star by month's end.

This celestial cleansing of the palate sets up a test for early risers. In **February** and **March 1997** Hale-Bopp slides over to the morning sky and is visible against the stars of Aquila, Vulpecula, and Cygnus. It now shines at magnitude 0.9 (early February) to –1.7 (end of March) and puts on the hottest part of its show. During the second half of March, however, the comet moves again into the evening sky, where

Already Spouting Comet Stuff. . .

By late August 1995, a large jet emerged from the core of Comet Hale-Bopp. A crack in the comet's frozen nucleus began blowing a stream of material outward, much like a firehose. Astronomers at the European Southern Observatory produced a false-color image (above) in which they subtracted Hale-Bopp's coma (black) to better study the jet material. A high-resolution image made at the Teide Observatory in the Canary Islands (above, right) shows the funnel-shaped jet.



Alan Fitzsimmons and Martin Cartwright, Queen's University of Belfast

A Beast in the Darkness

After several weeks of studying it, astronomers found that Hale-Bopp was no ordinary comet. The comet's nucleus (left) may span several dozens of kilometers rather than the typical few kilometers. Amazingly, Hale-Bopp's center lies buried in a vast dust cloud that stretches 2.5 million kilometers across. The shell of material being carried into the inner solar system, then, fills a volume of space larger than that of the Sun.

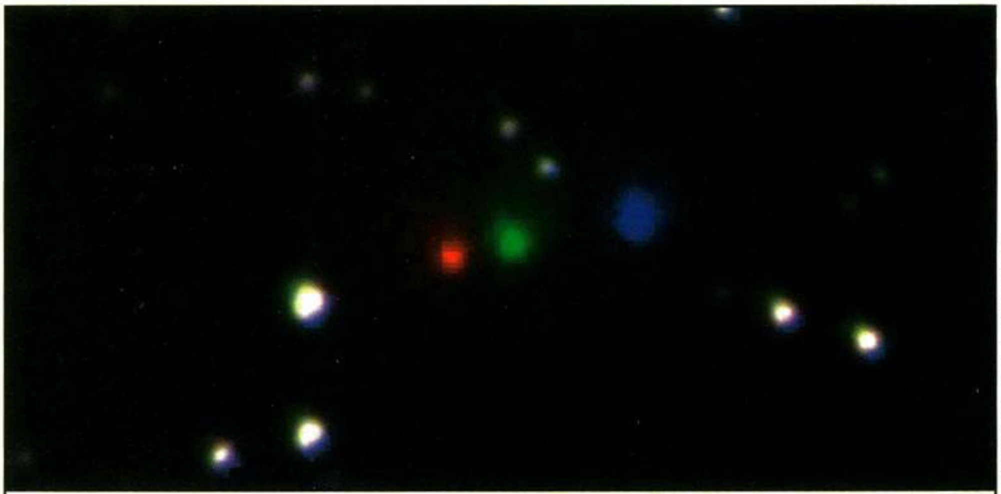
it stays until fading and slipping out of visibility in June, too close to the Sun. The comet's tail should be a remarkable sight, stretching some 15° to 20°, pointing away from the Sun, and standing tall as the comet moves slowly northeast along the spine of the Milky Way.

The best window for viewing the comet in February comes during the first three weeks of the month. Tantalizingly, because of the comet's motion from best visibility in the morning sky into the evening sky in March, Hale-Bopp eludes significant damage from moonlight throughout most of March, giving observers a nearly perfect shot at observing the comet's subtle features at their brightest. Observers in northern Asia who observe a total solar eclipse on March 9 see with their eyes alone the spectacle of Comet Hale-Bopp, shining at magnitude –1.2, along with the eclipsed Sun.

Hale-Bopp passes near a succession of deep-sky objects in February and March. Some of these provide opportunities for stunning, wide-field portraits of the comet with clusters, nebulae, and galaxies. On February 6, the comet passes south of M71 (NGC 6838), a bright globular cluster in Sagitta. Five nights later the comet squeezes between two planetary nebulae, the Dumbbell Nebula (M27) in Vulpecula and NGC 6905 in Delphinus, which are separated by 6°.

As it continues climbing the arch of the Milky Way, Hale-Bopp next encounters the open cluster NGC 6940 on February 19. From February 22 to 24 the comet skims the southern boundary of the Veil Nebula (NGC 6960, NGC 6992-5), likely passing over and temporarily obscuring parts of this glowing supernova remnant. From March 8 to 10 the good comet sweeps several degrees north of the galaxy NGC 7331 in Pegasus.

As a final triumph for the month, from March 23 to 27 Hale-Bopp passes 3° north of the Andromeda Galaxy (M31), between this large, bright spiral and its satellite galaxies NGC 147 and NGC 185. At this time the comet greatly outshines the great spiral galaxy, and the two form an odd pair. How much larger the comet's tail may appear is anyone's guess.


John Africano et al., AMOS and JPL

Hale-Bopp on the Internet

- Astronomy's Home Page. Complete, up-to-the-minute information on Hale-Bopp. http://www.kalmbach.com/astro/astronomy.html
- JPL's Comet Hale-Bopp Home Page. Many images and the latest on this brightening comet. http://newproducts.jpl.nasa.gov/comet/
- Comet Places on Line. A directory of images, data, and links on the Net. http://fly.hiwaay.net/~cwbol/astron/comet.html
- Comets. The University of Arizona's comet roundup. http://seds.lpl.arizona.edu/billa/tnp/comets.html
- International Comet Quarterly. Information on the primary comet publication along with sample pages. http://cfa-www.harvard.edu/cfa/ps/icq.html
- Gary Kronk's Comet Page. Images, positions, and magnitudes. http://wums.wustl.edu/~kronk/1995_ol.html
- NASA's Comet Observation Home Page. A smorgasbord of comet information and images. http://encke.jpl.nasa.gov/
- Tom Polakis' Comet Page. Quicktime and MPEG movies of the orbit of Comet Hale-Bopp. http://www.indirect.com/www/polakis/halebopp.html

Finally, the long festival of Hale-Bopp comes to an end. By **late March** and **April 1997**, the comet (now in Andromeda) shines its brightest, delighting observers as it dangles 15° to 21° above the northwestern horizon in the evening sky. The best period to see Hale-Bopp as it begins to dim extends through April 14, when the Moon again becomes a pest.

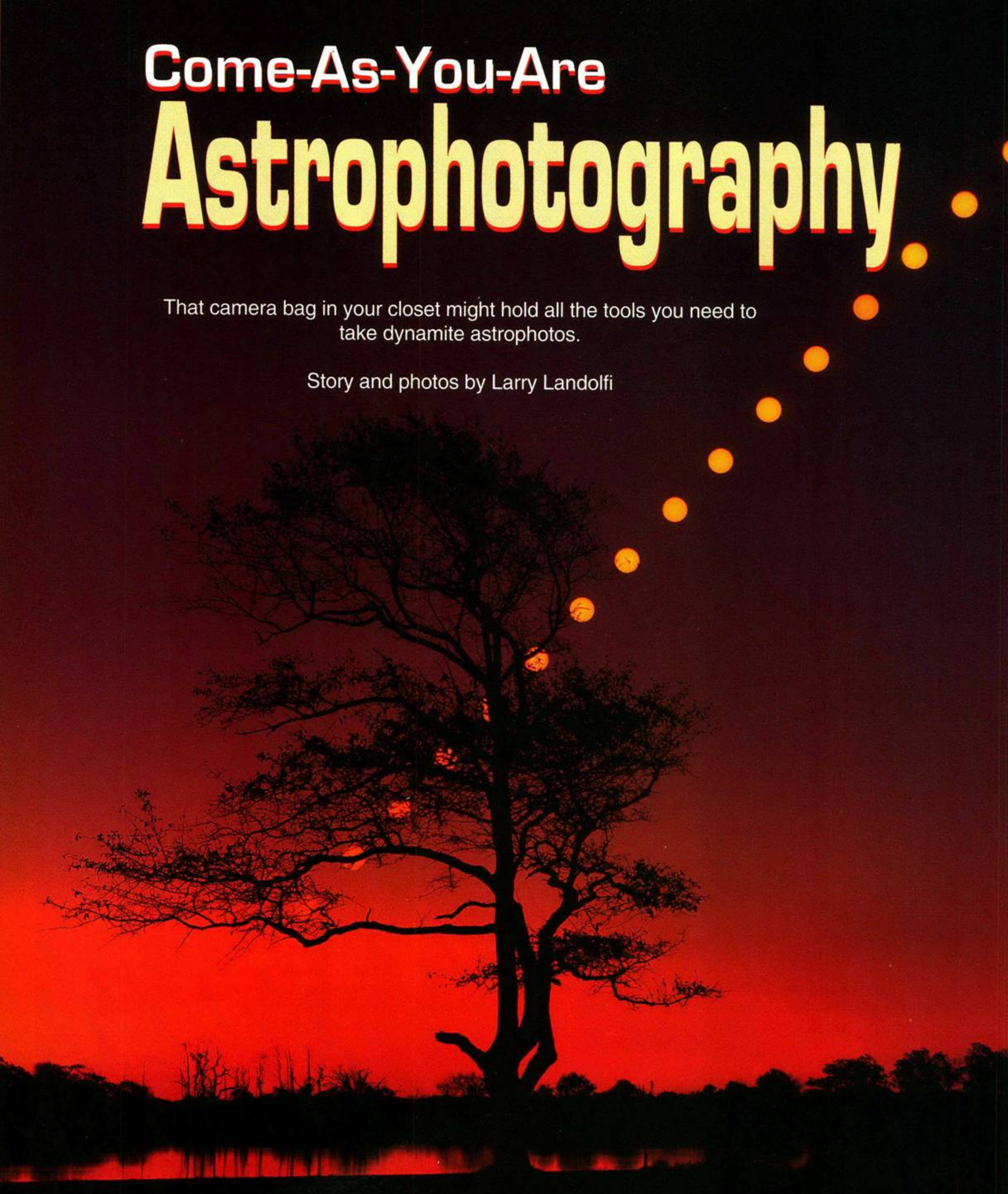
The comet's slow motion from Andromeda to Perseus again carries it close to the Sun. By the end of April it is difficult to spot, so close to the flood of sunlight in the early evening sky. The comet dims to magnitude –0.5, still brilliant, but temporarily outshone by the nearby Sun. Before hiding away, however, the comet in April affords a few encounters with bright sky objects. On April 4 it skims north of the edge-on galaxy NGC 891 in Andromeda. From April 6 to 7 Hale-Bopp passes between open cluster M34 and the faint galaxy NGC 1003, separated by 2°. On April 14 the comet skirts the southern edge of open cluster NGC 1342. Five days later the comet, now difficult to see and hindered by moonlight, moves between the California Nebula (NGC 1499) in Perseus and the Pleiades (M45) cluster in Taurus. And the great comet show is over.

Of course, all these predictions are just that — predictions. Comets are highly individual in the way they behave as they swing in toward the Sun, warm up, and grow tails. Kohoutek remains a potent lesson. But this time, almost 25 years later, those who calculate the details of Hale-Bopp's orbit and offer prognostications on its performance are handling the situation cautiously. Discouraged enough by the lackluster performance of Kohoutek, they are determined not to raise expectations too high. Despite the conservatism, then, Hale-Bopp at its best should at least be a delightful comet visible to the naked eye. ☐

Come-As-You-Are Astrophotography

That camera bag in your closet might hold all the tools you need to take dynamite astrophotos.

Story and photos by Larry Landolfi



SUNRISE COMPRESSES ITSELF into one photo through the magic of multiple-exposure photography. This photo used a camera, tripod, cable release, and a homemade filter.

Astrophotography has certainly progressed over the past 15 years. But with progress comes higher equipment and film costs, not to mention steeper learning curves to master some pretty sophisticated techniques. Are there astrophoto methods out there that don't cost a mental or financial arm and a leg?

The short answer is a resounding yes. You can land easy (and inexpensive), guaranteed-to-be-interesting astroimages by applying some three methods that take advantage of something as basic as the Earth's rotation.

Each method uses photo gear that's probably sitting in your camera bag or hall closet right now. All you need is a 35mm camera capable of multiple exposures and that doesn't draw battery power on the "bulb" setting. You'll also need a sturdy tripod, a cable release, a light meter, a 50mm lens, and, if you own one, a telephoto lens with a minimum focal length of 200mm.

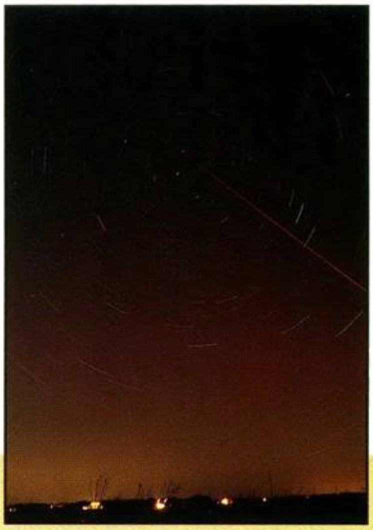
Astrophotography 101

As a rule, two of the three methods we'll explore use slow, fine-grained slide films such as Fuji Velvia or Kodak's Elite 100. One exception to the slow-film rule involves taking the simplest of all astrophotos, the "star trail" photograph.

You've probably seen this type of picture many times without ever knowing how easy it is to take. Load your camera with Ektachrome 200 or 400 slide film and attach a lens with a focal length between 28mm and 50mm. Place the camera on a tripod and focus the lens to infinity. Next, aim the camera towards the North Star after composing an interesting terrestrial foreground. Set the camera's shutter speed dial to "B" and then, using a cable release, lock the camera's shutter open to capture Earth's rotation on film as a series of star streaks. As starting points, try exposures of a half hour at f/4.0, an hour at f/5.6, or two hours at f/8.0.

Light pollution today makes it difficult to take a long exposures like these from a typical urban backyard. Try shooting from a location that's well-shielded from nearby streetlights. Consider an expedition under rural skies. Regardless of where you end up, don't expose too long if the sky seems washed out. Start with a 15-minute exposure and work up to the recommended times. Even the most subtle of light pollution conveys a green, blue, or orange cast to the pictures.

The type of film you use will also determine a picture's sky color. Film's chemical make-up can shift the color balance toward certain hues during long exposures. Kodachrome shifts toward red, Fujichrome toward green, and Ektachrome toward blue. With this in mind,

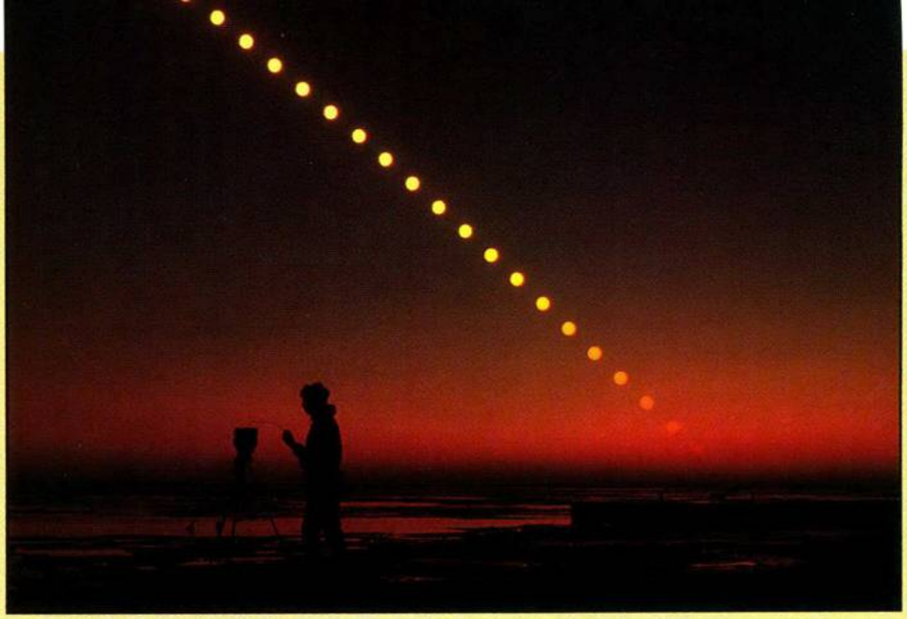


Time-Warped Star Trails

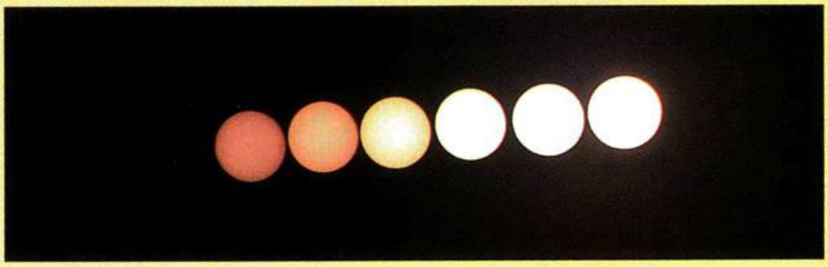
LOAD A CAMERA with fast film, set it up on a tripod, and open its shutter for an hour or so while Earth does the rest: That's all the work required to take star-trail photos like these. Aiming at the North Star captures the night sky as it wheels around the north celestial pole (top left). Note the horizon shows off a hint of greenish aurora as a meteor cuts through the right half of the frame. Ghostly silhouettes (top right) not only add depth but mood to star trail photos. If a foreground object has detail that might add to the photo, "paint" it with a white or red flashlight (right).

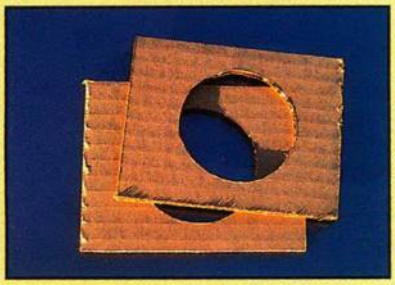
Discover Sun-dot Photography

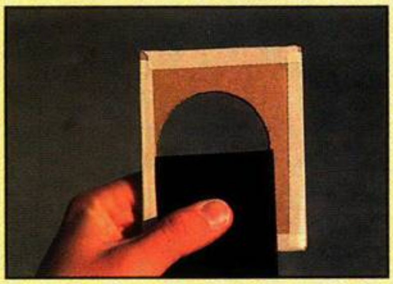
YOU AND YOUR NEW FILTER will record multiple exposures of both sunrise and sunset. A two-hour-plus multiple exposure (left) catches sunrise behind the skyline of Manhattan. This Long Island Sound sunset (right) ends with a self-portrait by the photographer.

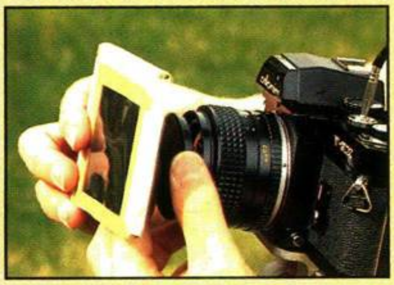


CRAFT A SUN-DOT PHOTOGRAPHIC FILTER first by cutting a cardboard frame for it to fit into (bottom left). The filter itself is made from two layers of T-Max 100 black & white that was first exposed to direct sunlight and then processed normally. Sandwich film onto or into the cardboard frame (bottom middle). Hold the Sun-dot filter in front of the camera lens during exposures (bottom right). The camera lens is capped at all other times. Run a test-exposure to figure out which shutter speed works best with the filter you've made (right). Never look through the filter toward the Sun.









I've found that the Ektachrome family works best for star trail photography. Its color shift conveys a pleasing dark blue-black sky.

Sun-Dot Photography

There's another form of star photography that's both simple and dramatic. To shoot the Sun, our daytime star, I've created what I call a "Sun-dot" filter. This simple tool helps capture on a single film frame a dramatic time-lapse photograph of the Sun rising or setting.

The Sun-dot is a photographic filter that lets just enough sunlight through to create an image on film. It *is not* a visual filter that lets you sight the Sun through the camera. To do so is dangerous and could result in blindness. Never use a Sun-dot to observe the Sun.

Make the filter by having a photo processor develop a 12-exposure roll of 120 sized T-Max 100 black-and-white film that's been opened and exposed to direct daylight for at least a minute. Cut and sandwich together two layers of the processed film that are long enough to cover the front of a 50mm lens. Mount the pieces in cardboard to let you hold the filter in front of the lens while taking a picture.

The processed T-Max film's density might vary from processor to processor, so you'll have to calibrate your Sun-dot filter. Try a variety of test exposures on slow slide film (less than ISO 100) to find out what yields the best-exposed solar image. With a wide-angle or 50mm lens set at f/8, start with a 1-second exposure and progress through 1⁄500 second. Make sure the filter covers the lens before opening the shutter. Don't worry about where the Sun's image falls on the frame. Pointing the camera in the Sun's general direction is enough to capture it in a wide-angle or 50mm lens.

After processing the slide film, note what shutter speed is best suited for your particular Sun-dot filter. For the most part, though, the filter is very forgiving when it comes to exposure; I've overexposed the Sun by 3 or 4 stops and still produced usable Sun images.

It's interesting to note that Kodachrome 25, Fuji Velvia, and Kodak Elite 100 give pleasing yellow-orange Sun images with the Sun-dot, while Kodachrome 64 yields a white image.

Poetry in Motion

The Sun-dot is designed to let you take multiple-exposure photos of sunrises. To take this type of picture requires a camera with a light meter or a hand-held light meter, a cable release, a sturdy tripod, and a camera body that can take multiple exposures.

First, figure out where to shoot from. Explore a candidate site the morning before to note where the Sun rises, as well as the angle its direction of travel makes with the horizon. The Sun rises at about a 45° angle for U.S. residents, rising at a "shallower" angle around the winter solstice in December and a little "steeper" around the summer solstice in June. Keep this in mind when you plan a vertical or horizontal shot. After finding an ideal spot, mark it so you'll know where to set up the next morning.

The next day, show up at the site about an hour before sunrise. Attach your camera to a tripod and mentally frame the Sun's path in the viewfinder, along with any interesting horizon landmarks. Now make sure that the camera is rock steady by trying to move it in every possible direction. If it stays put, you're ready for twilight.

A sunrise sequence photo breaks down into two parts: capturing morning twilight (the "main exposure") and taking multiple exposures of sunrise. The best time to shoot a perfectly-balanced twilight scene comes about 35-30 minutes before sunup. Take a light meter reading on the bright area just above twilight's red-orange glow and click off a picture.

After shooting a twilight scene, cock the camera's shutter without advancing the film, as you will do for all the exposures that follow. Set the lens aperture to f/8 and the shutter speed to a value obtained during the Sun-dot calibration tests. From here on out, exposures will be done through the Sun-dot filter.

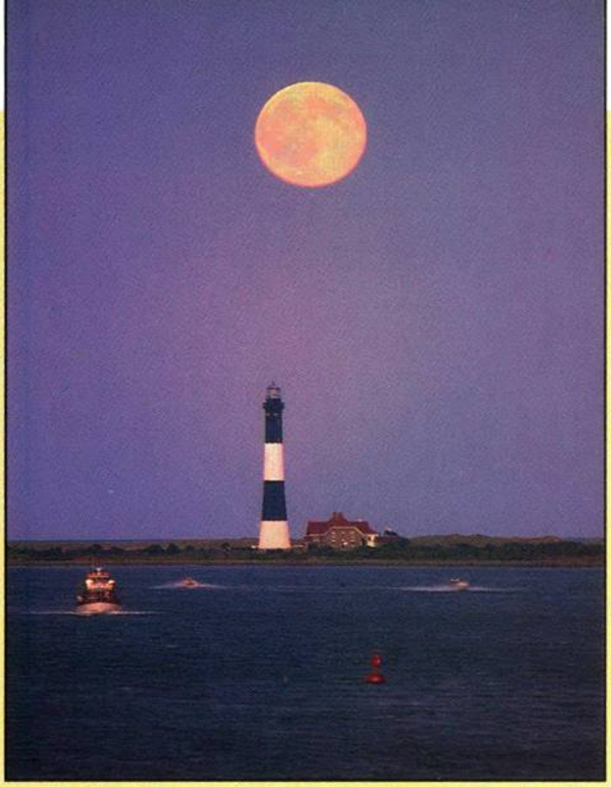
As soon as the Sun clears the horizon, it's time for the second part of your picture. But first, a caveat.

For the sake of the camera's mirror (and other internal parts), at no time should the Sun shine through the lens. The lens acts as a magnifying glass and will quickly fry the inside of your camera. Keep the lens cap on at all times, except when holding the Sun-dot filter directly in front of your camera during an exposure.

How often should you expose? Earth's rotation causes the Sun to move through its own diameter every two minutes. With this in mind, snap a picture every four to ten minutes. The interval I have found works best is six minutes; this seems to leave a perfect amount of space between each solar image.

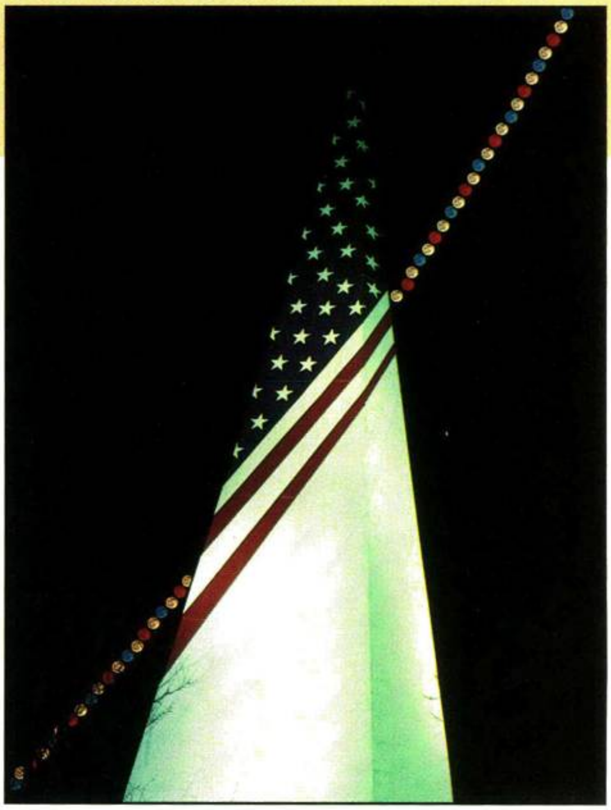
How long should a sunrise sequence take to photograph? If a camera fitted with a 50mm lens is arranged vertically, the Sun takes about 2 to 2½ hours to clear the top right corner of a picture frame. If you're shooting a horizontal picture, plan on shooting for 1½ hours.

To shoot a setting Sun sequence, simply reverse the order of exposures. There is one compelling reason for shooting a sunrise, however: Nothing is more disappointing than spending 2 to 2½ hours photographing a setting Sun just to have clouds roll in and put a damper on the twilight shot. With a sunrise sequence, the main shot gets taken at the outset. If clouds roll in, you can go back to bed without having wasted too much time.



The Moon In Space and Time

EARTHLY LANDSCAPES BLEND INTO MOONRISE as daylight relinquishes its grip on the night sky. A long telephoto lens squeezes a bridge into the same picture as this rising gibbous Moon (left). Towering objects lend themselves to vertical pictures, as this photo of a full Moon rising next to a lighthouse shows (top right). Slip off the telephoto to apply some multiple-exposure techniques to the Moon. Shooting it through colored filters lends patriotic favor to this flag-draped monument (bottom right)



Do a Telephoto Moon

Another easy astrophoto target lingers at sunrise and sunset. The almost-full Moon often plants itself among interesting landmarks that dot the horizon. Its coppery hue color combines with the dramatic colors of twilight to create a visually stunning picture just waiting to be taken.

All you need to shoot a rising Moon is at least a 200mm telephoto lens and a tripod to hold the camera steady. Determine what shutter speed to use by metering the surrounding twilight and then underexpose by a ½ to a full stop.

Once darkness falls and the Moon rises higher, apply the same multiple-exposure techniques used above to capture the Moon's motion through the sky. Compose a scene in the camera viewfinder that anticipates the Moon's path through a tree, or past a tower or building. For proper exposure, use what I call the f/11 rule: Set the lens aperture to f/11 and the shutter speed to a value that's closest to the reciprocal of your film's ISO rating. For example, a camera loaded with ISO 50 film would shoot at 1/60 of a second, the shutter speed closest to 1/50.

Because the Full Moon looks so white, try shooting it through a variety of colored filters. Using red, green, and blue filters I've blended many multiple-exposure Moon sequences into a cavalcade of color. Experiment with other combinations of scenes of filters to create dreamscapes of your own.

These simple techniques offer unlimited possibilities since any clear sky always presents the Sun, Moon and stars as targets. Soon you'll have an eagle eye peeled to the heavens, always looking for photographic opportunities. This will lead to an increased awareness of what's going on in the sky, which not only benefits you as an astrophotographer in particular, but as a skywatcher in general. ☐

Larry Landolfi enjoys photography and astronomy when he's not working for the U.S. Postal Service. This is his first feature article for ASTRONOMY.

Tracking a Distant Comet World

Follow an enigmatic, burned-out comet as it reaches visibility for backyard astronomers.

by David J. Eicher

Chiron is one of the odd ducks of the solar system. Discovered in 1977 and thought to be a strange asteroid, the object startled astronomers eleven years later when it developed a gaseous cloud of particles — astronomers had to reclassify it as a comet and rethink the relationship between asteroids and comets.

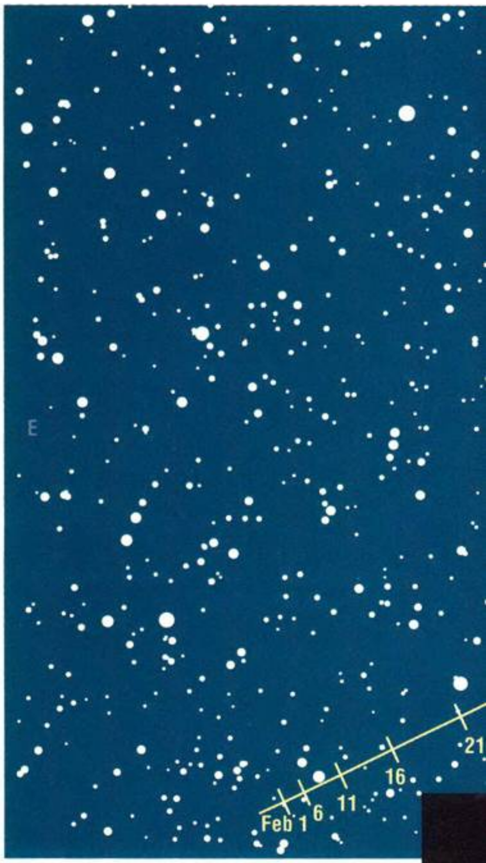
This distant denizen of the Sun's domain orbits the Sun in a highly elliptical path that carries it out to the neighborhood of Uranus and inside the orbit of Saturn. (See "Chiron: Interloper from the Kuiper Disk?," August 1994.)

Where to Find Chiron

Date	R.A. (2000.0)	Dec.	Mag.
Jan. 15, 1996	12h48.2m	–8°03'	15.7
Jan. 25	12h48.8m	–8°07'	15.7
Feb. 4	12h48.8m	–8°06'	15.6
Feb. 14	12h47.9m	–8°00'	15.5
Feb. 24	12h46.5m	–7°50'	15.4
Mar. 5	12h44.5m	–7°35'	15.4
Mar. 15	12h42.0m	–7°17'	15.3
Mar. 25	12h39.3m	–6°57'	15.1
Apr. 4	12h36.4m	–6°35'	15.1
Apr. 14	12h33.7m	–6°13'	15.2
Apr. 24	12h31.2m	–5°52'	15.3
May 4	12h29.1m	–5°33'	15.4
May 14	12h27.5m	–5°17'	15.5
May 24	12h26.5m	–5°04'	15.6
June 3	12h26.2m	–4°56'	15.6
June 13	12h26.6m	–4°53'	15.7
June 23	12h27.6m	–4°53'	15.7
July 3	12h29.3m	–4°59'	15.8
July 13	12h31.7m	–5°08'	15.8

On February 14 Chiron reaches perihelion, its closest point to the Sun, and on April 1 it passes as close as it gets to Earth on this inside leg of its 51-year path. It's a rare event: The last time Chiron reached perihelion, the Third Reich had collapsed and the war in the Pacific was heating up as allied naval and air forces inflicted a series of crushing defeats on Japan. Now, half a century later, most of us get our first chance to see this distant world. It's the first perihelion for astronomers armed with modern telescopes, too.

Since the discovery of Chiron and of its peculiar nature, astronomers have classified it as a comet with an unusual orbit that has nearly burned itself out (see box below). Astronomers believe Chiron may have escaped the so-called Kuiper belt, the storehouse of short-period comets lying beyond Neptune. Though its nature is still mysterious, Chiron is believed to be between 90 and 130 miles across. Because it is so distant, however, the burned-out comet is quite faint in our sky.



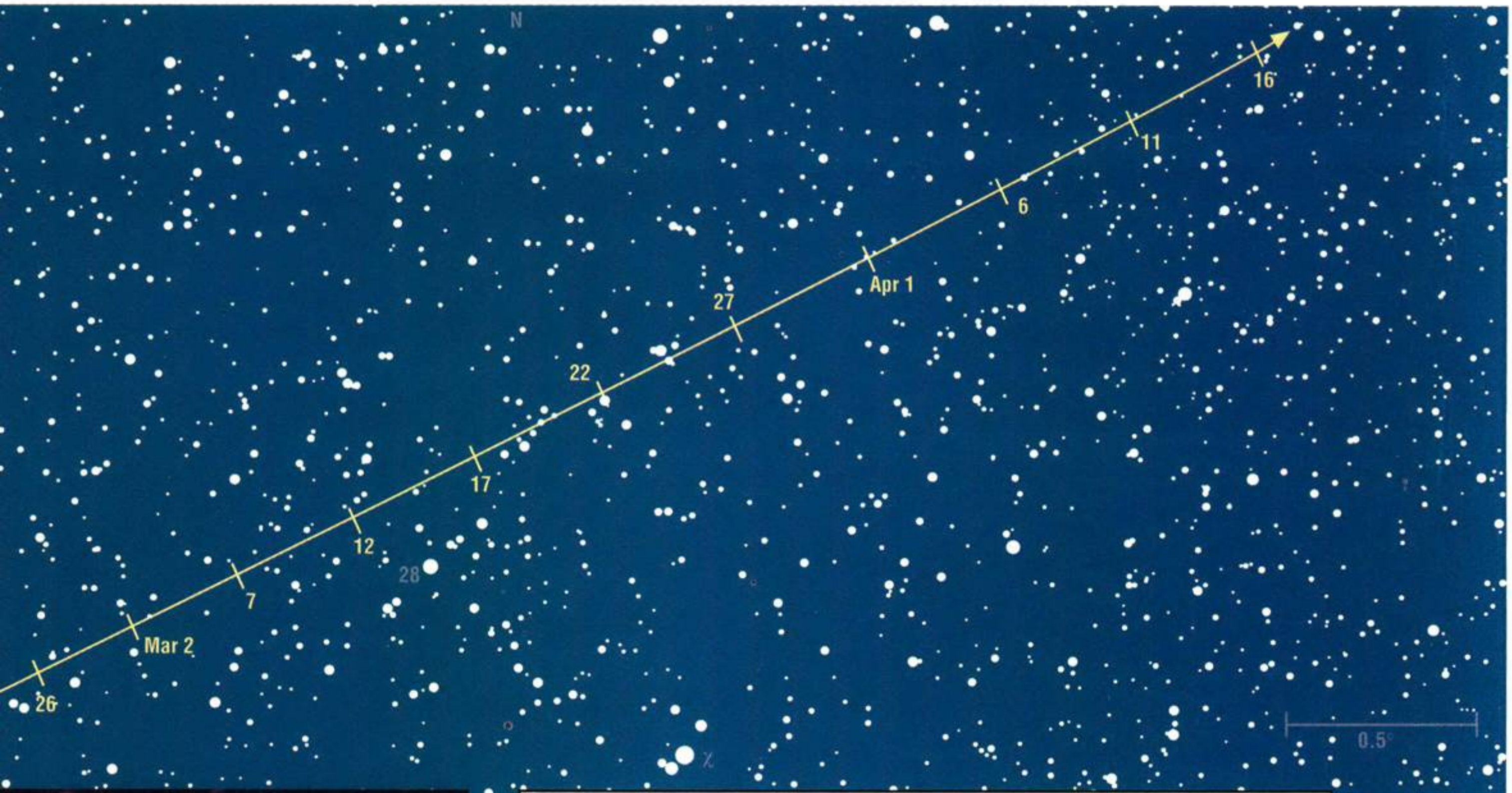
A TINY POINT AT CENTER marks the feeble light from Chiron, an enigmatic comet (right). The telescope tracked on Chiron for this image, creating stars that trailed.

Still, it's a kick to haul a sizable telescope into a dark field and look at Chiron. Though the object appears simply as a faint "star," moving at a snail's pace through Virgo, the magic lies in

Chiron's Unnatural History

Charles Kowal found a peculiar object on his photographic plate on November 1, 1977. The image, made with the 1.2-meter Schmidt telescope at Palomar Observatory, showed an asteroid, designated 1977 UB. Kowal calculated its orbit as unlike any other asteroid's and dubbed the object Chiron. Subsequent searches uncovered images of Chiron taken as early as 1895.

In 1988 astronomers were astonished when Chiron developed a coma, revealing a comet-like aspect. The dual asteroid/comet nature of Chiron and five other similar objects discovered since then led to the name Centaurs ("half man, half horse") *to describe* this peculiar class of objects.



Denis Bergeron

Orbital Elements for Chiron

Epoch January 17, 1996

Perihelion Time (*T*)	February 14.7525, 1996
Perihelion Distance (*q*)	8.4639422 AU
Eccentricity (*e*)	0.3831118
Argument of Perihelion (ω)	339.58061°
Longitude of ascending node (Ω)	208.65735°
Inclination (*i*)	6.93524°

knowing what you're looking at. To see Chiron requires a dark, moonless night, good or better transparency, steady seeing, and a telescope of at least 12 inches aperture. Success will come more easily with a 14-inch, 16-inch, or larger scope. To see Chiron requires more than a peek through the eyepiece: Carefully sketch the field you believe contains Chiron based on the finder chart above, then come back a night or two later and sketch it again. The "star" that has moved is Chiron.

Start looking in mid-January, when Chiron rises in the early morning sky about 8° northwest of the bright star Spica. During the middle days of the month the object moves between galaxies NGC 4699 and NGC 4818, which are separated by 2°. As January and February seize the calendar, Chiron and its host constellation Virgo move into the early morning sky, allowing several viewing hours before dawn. The best moonless window in January comes during the last two weeks of the month.

In February, the Moon does not interfere significantly during the first few days of the month nor for the last two weeks. During this period Chiron brightens gradually from magnitude 15.7 to 15.4, becoming somewhat easier to distinguish from the faint field stars in the area.

March and April bring not only warmer weather but carry Chiron into a more convenient viewing time. Virgo and its attendant now become late evening objects visible throughout the night. The best windows for moonless observing present themselves during the first few days of March and the last two weeks of the month, and from about April 10–25. By late March and early April Chiron reaches its peak magnitude of 15.1, so this period offers the greatest opportunity to see this distant world.

From spring through early summer, Chiron is placed for easy observing in the evening sky. It remains at magnitude 15.6 or brighter throughout May, can be seen throughout June, and slowly sinks into the horizon glare by July, too close to the Sun to be seen. The best windows for avoiding Moon interference are about May 8–23 and June 5–23.

By July 20 Chiron approaches the south side of the galaxy NGC 4731, but by then the pair are steeped in twilight. The Chiron hunt will then be over, and those who have wielded large telescopes will have seen for themselves one of the confounding members of the solar system. ☐

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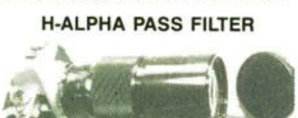

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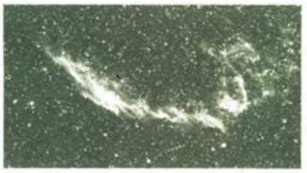

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0.96" LUMICON DEEP-SKY Filter threads into most 0.96" eyepieces	$59.50
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72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $10, 82mm $16)	$299.50
2" Rear Cell Filter, fits SCT's Deep-Sky, **$119.50** UHC, O-III, H-Beta,	$199.50
1¼" LUMICON UHC Filter threads into most 1¼" eyepieces	$99.50
48mm LUMICON UHC Filter (1.75" aperture) fits most 2" eyepieces	$199.50
DEEP-SKY and choice of **UHC, O-III or H-BETA** Filter (**Save 11%**) 1¼" **$159.50**; 48mm	$279.50
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. **1¼"** **$99.50, 48mm**	$199.50
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines **1¼" $99.50, 48mm**	$199.50
Telephoto lens adapter for 2" or 48mm filter. Select 46, 49, 52, 55, 58mm	$7.95
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**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

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LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**

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MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller ... **$595**

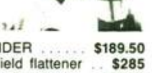
Temperature controller for any HYPER-KIT **$75**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars. †U.S. Patent 4,448,500
Specify Camera and Telescope type.

NEWTONIAN EASY-GUIDER™



Full aperture. Installs in seconds. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER	**$189.50**
48mm Coma corrector/field flattener	**$285**
3X Relay Diagonal (see photo)	**$99.50**
Illuminated reticle eyepiece, pulsed	**$109.50**

Guider for Hasselblad **$409,** Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

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Pentax 6X7 **add $119;** Pentax 645 **add $139**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10" Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ..... **add $99.95**
Adapter for Hasselblad **$295,** Mamiya 645**$149**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$109.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.
2. Cable release for long exposures .. **$9.95**

3. **LUMICON Digital Drive Corrector** . **$249**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 30Hz/90Hz variable output controls telescope drive. 60Hz digital reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Dec. reverse switch for Newtonians.
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HYPERSENSITIZED FILM

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SR1600
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NEW
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YES! WE STILL HAVE FUJI HG400!

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
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SR-G3200, fastest of all, color neg	24	**$14.95**
Kodak Ektar 1000 fast, fine grain	24	**$12.95**
Fuji HG400 fine grain color neg.	12	**$14.95**
Ektachrome 1600, fast slide film	24	**$14.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

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LED FLASHLIGHT $14.95

LUMICON LUMILITE™ Red LED Flashlight

This red LED flashlight preserves night vision. It uses 2 AA cells (included!) which last 60-100 hours.

LUMILITE red LED flashlight	**$14.95**

DRIVE CORRECTORS

LUMICON
UNITRAK

LUMICON UNITRAK DRIVE CORRECTOR

Operate your telescopes ***anywhere!*** Use the single-axis Unitrak with a 12V DC car battery. The dual-axis drives are for photography and use either 12V DC or 125V AC.

Unitrak™ single-axis corrector	**$99.95**
LUMICON DX200 dual-axis correc.	**$249.00**
DX2BP incl. battery & charger	**$298.00**
Convenient rechargeable Porta-Pac battery: 12V DC Porta-Pac (5AH) & recharger	**$89.50**

48MM COLORED FILTERS

FOR EVERY NEED

Select 48mm UV, Red, Yellow, Green (ea.)	**$19.95**
48mm Cyan (absorbs red)	**$69.00**
48mm High Performance Blue (95% T)	**$49.00**
48mm Tri-Color Blue (80% T- 400nm)	**$49.00**
48mm Ultraviolet (85% T- 370nm)	**$49.00**
Color Separation Set: cyan, red, yellow, blue	**$149**

RICH FIELD! 2° in 8'' SCT

NOW ONLY
$99.50

LUMICON Rich-Field Viewer on C-8 with LUMICON 2'' star diagonal and 2'' eyepiece.

The LUMICON Rich-Field Viewer fits **all** commercial Schmidt-Cassegrain telescopes. It has a high-performance coated achromatic focal reducing lens with 50mm or 80mm clear aperture for **totally unvignetted viewing** with 2'' or 1¼'' eyepieces. It is available in several combinations depending on the eyepiece and field-of-view you desire (see chart below).

LUMICON Rich-Field Viewer	**$99.50**
Giant Rich-Field Viewer (10-14'')	**$250.00**

Optional Eyepiece	TRUE FIELD	Price
Meade 32mm Plossl	1.4°	**add $99**
Meade 32mm 2'' Wide-Field†	1.9°	**add $439**
Meade 40mm 2'' Wide-Field†	2.4°	**add $498**

†*Includes 2'' enhanced aluminum Star Diagonal (may not reach focus on some telescopes).*

PROTECTIVE DUST COVERS

Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼'' O.D. plug, seals focuser	**4/$2**		
2'' O.D. plug	**2/$2**	3½'' O.D. plug	**$1.50**
1¼'', 1⅜''	**3/$2**	7½''	**$10**
1½''	**2/$2**	9½'', 10.4''*	**$15**
2''	**2/$2**	12½'', 12⅞''*	**$20**
2⅛''	**2/$20**	15.6'', 16''*	**$28**
5½''	**$6**	19'' (DS-16)	**$35**
*Fits Odyssey		21'' (Odyssey-II)	**$35**

MEADE 8'' - 16'' LX200

NEW! 8'' - 10'' LX50

8'' LX50
$1495
16'' LX200 $14,950

Meade 8'' LX200 Telescopes

LX50 - includes dec. motor, hand controller. **LX200** - full computer control w/64K obj. mem. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your LX200 Schmidt-Cassegrain.

NEW! 8'' LX50 w/wedge, tripod, hand controller ($115 P&S)	**$1495**
8'' LX200 w/computer ($105 P&S)	**$2495**
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10'' LX200 w/computer ($145 P&S)	**$2895**
12'' LX200 (f/10 only)($215 P&S)	**$3995**
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Dew Shields: 8'' **$119**; 10''	**$129**
12'' **$189**; 16''	**$289**

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4'' f/10 w/motor ($40 P&S)	**$699**
Model 2120B 10'' w/wedge, tripod	**$1599**

PHOTOGRAPHY ACCESSORIES

Cassegrain EASY-GUIDER 4'', 8'', f/6 or f/10	**$249**
Giant EASY-GUIDER for 10''/12'' f/4-f/10	**$395**

MEADE STARFINDERS

New 8'' f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions. These are complete telescope systems with motor drive (equat. only), mount, finderscope and 25mm (=48X) eyepiece.

6'' f/8 Dobsonian Starfinder ($46 P&S)	**$325**
6'' f/8 Equat. Starfinder 6(add $79 P&S)	**$599**
8'' f/6 Dobsonian Starfinder (add $59 P&S)	**$425**
8'' f/6 Equat. Starfinder 8 (add $89 P&S)	**$699**
10'' f/4.5 Dobsonian Starfinder ($85 P&S)	**$595**
10'' f/4.5 Equat. Starfinder 10 (add $99 P&S)	**$799**
12.5'' f/4.8 Dobsonian Starfinder ($95 P&S)	**$795**
16'' f/4.5 Starfinder 16 (ship. freight COD)	**$2495**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated packing & shipping charge to the price. Slightly lower P&S for payment by check. LUMICON showroom prices are $99 higher.

ACCESSORIES

LUMICON carries all Meade accessories.

LUMICON Single axis drive corrector	**$99**
LUMICON DX200 Dual-axis drive cor.	**$249**
Meade 47M Dual-axis drive corrector with tangent arm & electric declination	**$475**
LUMICON DX2BP Dual-axis drive corrector with built-in battery pack	**$299**

SKY VECTOR™ $249!!

New Lower Prices — Higher Performance

LOW PRICE—from $249

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $249

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $289

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

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IMPROVED!—5500 Additions / Corrections

NGC-Sky Vector™
OFF ON
DIM
MODE
ENTER
UP
DOWN
LUMICON®

Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½'' f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2'' lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2'' EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8''.

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2'' EASY-GUIDER	**$189.50**
2'' EASY-GUIDER (Mamiya 645)	**$239.50**
2'' Adapter for Pentax 6X7	**$129.00**
2'' Adapter for Hasselblad	**$229.00**
2'' Adapter for Bronica SQ-A	**$175.00**
2'' Extension for viewing	**$26.00**

2'' DELUXE BARLOW

1.8x Multiplier Lens (2'' Barlow)

LUMICON 1.8x Multiplier Lens (2'' Barlow)	**$259.00**

LUMICON ACCESSORIES

LUMICON, Livermore, CA 94550 (510) 447-9570 FAX (510) 447-9589

LARGE UV/DUST SEAL

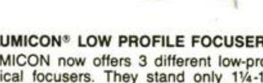
Protect the optics of your 8-14'' Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080	**$119.50**
UV/Dust Deal for Celestron C-8	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14	**$89.50**

LOW PROFILE FOCUSERS

New! Thread-on for Odyssey

FROM $69.50



LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½'' above the telescope tube. Use the 1¼'' or 2'' versions for viewing. Use the 2'' non-rotating focuser for convenient photography with the LUMICON 2'' EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7'' OD, 9½'' OD, 12½'' OD, 16'' OD, 21'' OD.

LUMICON 1¼'' Helical Focuser	**$69.50**
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LUMICON Non-rotating Helical Focuser	**$129.00**
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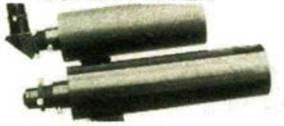
3 handles for non-rotating focuser	**$12.95**
2''/1¼'' adapter w/48mm filter threads	**$20.00**
2'' LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™



Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼'' 50mm Finderscope **$69.50**, right-angle	**$69.50**
1¼'' straight-thru 80mm SUPER-FINDER	**$189.50**
1¼'' right-angle 80mm SUPER-FINDER	**$199.50**
1¼'' right-angle version, w/star diagonal	**$239.50**
25mm Cross-hair 1¼'' eyepiece (12X)	**$49.00**
Large mounting rings for 80mm Finder	**$55.00**
1¼'' Star Diagonal **$49**, Mounting Brackets,	**$39.50**
1¼'' 45° diagonal for correct left-right views	**$59.50**

LOTS OF ADAPTERS

2'' adapter for C-8, Meade 2080, etc.	**$29.50**
2'' adapter for C-80, C-100 refractor	**$39.50**
2'' adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2'' adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

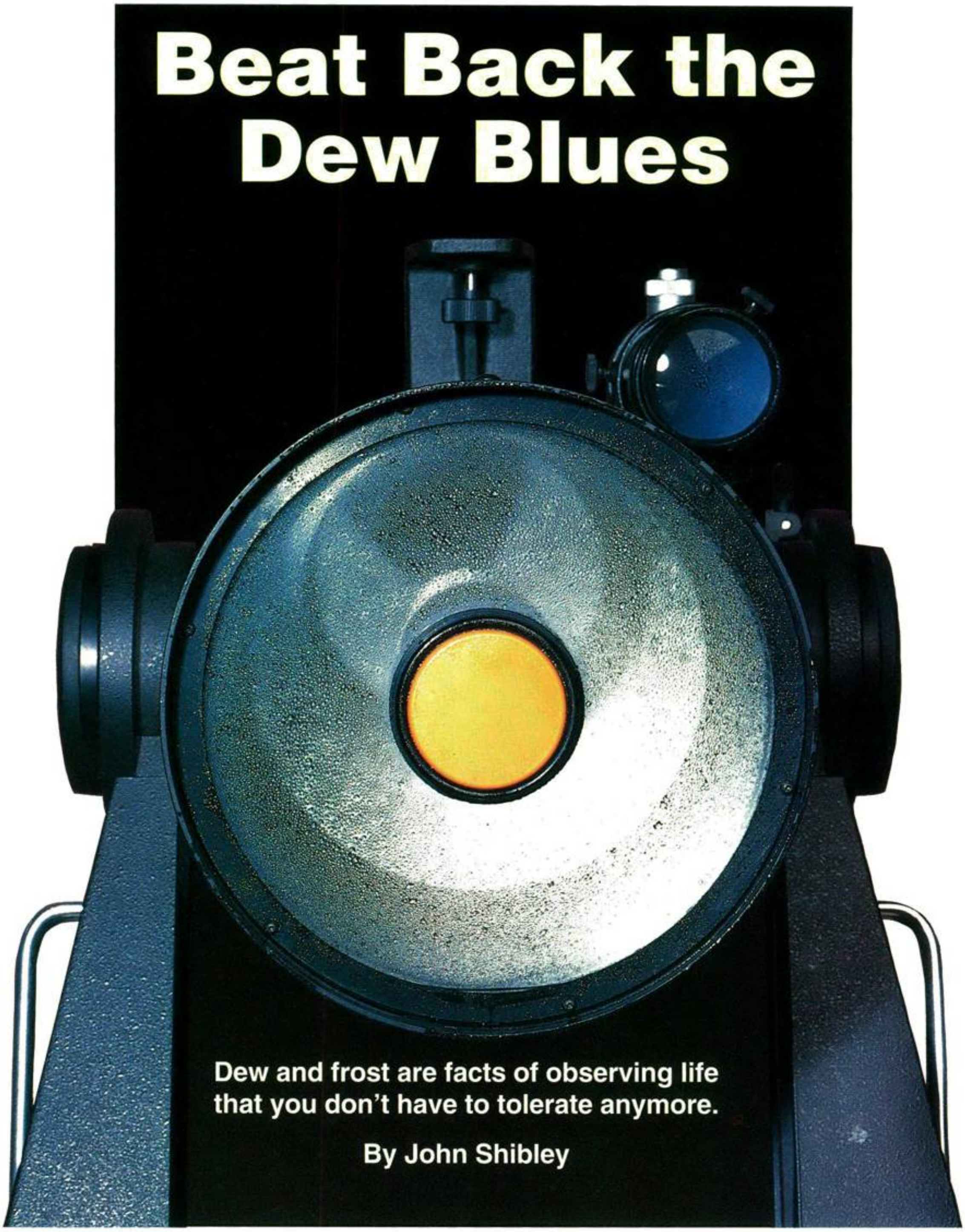
1'' long 1¼'' OD thread-in extension	**12.00**
2½'' long extension (holds 1¼'' filters)	**19.50**
4½'' long extension for 1¼'' eyepieces	**$25.00**
3'' long extension for 2'' eyepieces*	**$29.00**
2'' long extension for 2'' eyepieces*	**$29.00**

VIEWING ADAPTERS

2''/1¼'' reducing bushing,threaded 48mm*	**$25.00**
2''/T-thread adapter, threaded 48mm*	**$25.00**
T-thread/1¼'' adapter	**$25.00**
F/10 2'' or 1¼'' eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2'' Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

Beat Back the Dew Blues



Dew and frost are facts of observing life that you don't have to tolerate anymore.

By John Shibley

All photos: ASTRONOMY: Jim Forbes

If poet Carl Sandburg had been an amateur astronomer, he probably would have selected a more colorful metaphor than "cat's feet" to describe the approach of fog. For fog is a merely dew that's out of control, and dew is the archenemy of every sky observer. It coats everything optical and leads to loads of frustration.

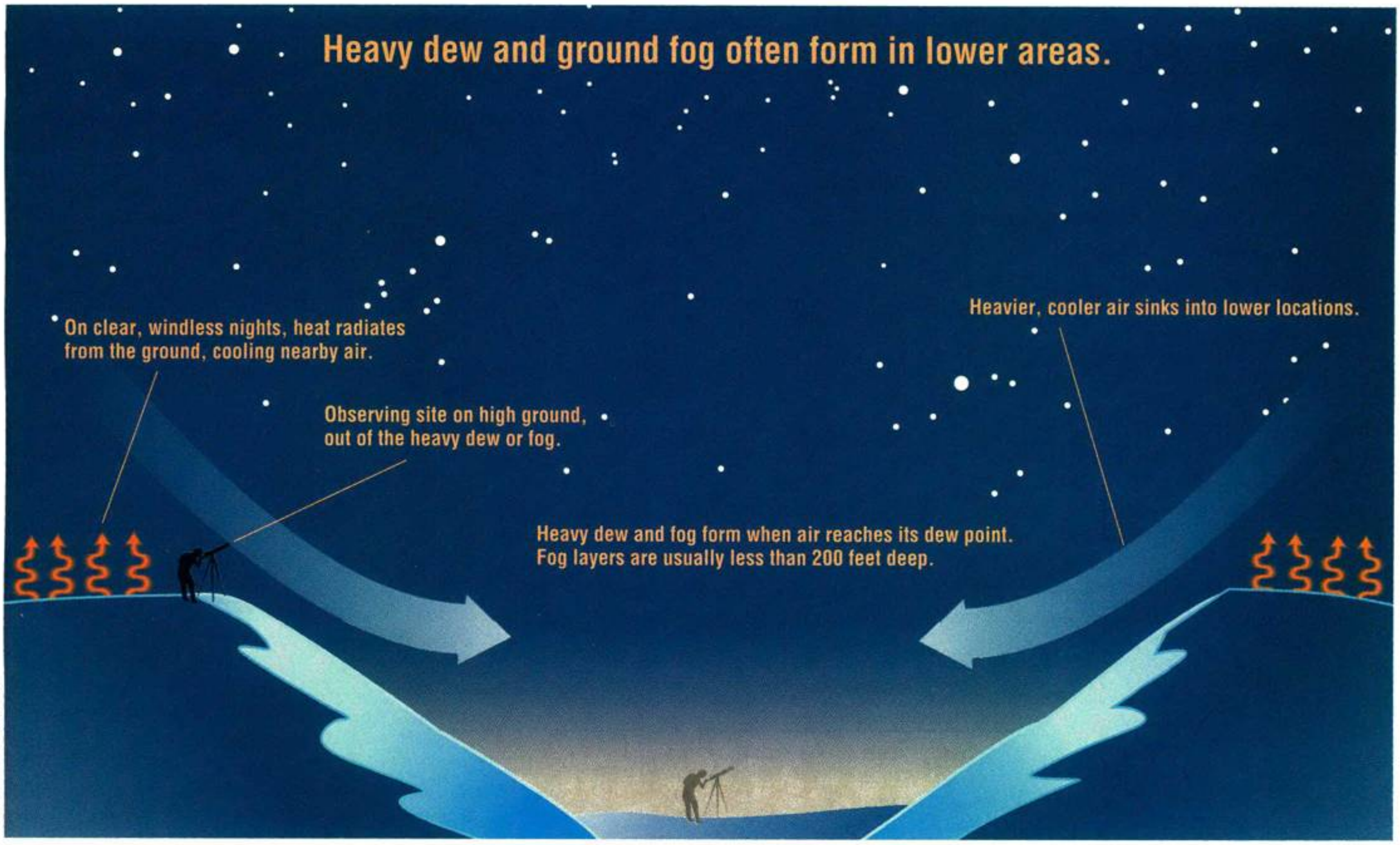
But no longer does dew's moist approach have to spell the demise of an observing session. It's easy to keep dew at bay by knowing what makes the aqueous enemy tick and applying a few simple countermeasures.

Know Your Enemy

Let's start by taking a trip on a molecular level.

The air you breathe is actually a swirling maelstrom of atmospheric gas and molecules of water vapor. The warmer the air, the more water vapor it holds. As air cools, it reaches a temperature called "dewpoint." At that temperature, water molecules slow down and collide with one another to stick together — forming liquid water.

This is precisely what happens when dew forms. Water that's been evaporating all day is suspended in air as a gas. After the Sun sets, a primary source of


Heavy dew and ground fog often form in lower areas.
On clear, windless nights, heat radiates from the ground, cooling nearby air.
Observing site on high ground, out of the heavy dew or fog.
Heavier, cooler air sinks into lower locations.
Heavy dew and fog form when air reaches its dew point. Fog layers are usually less than 200 feet deep.

ASTRONOMY: Gary Kachar

energy disappears that's been keeping all those molecules moving. When the air temperature reaches dewpoint, water molecules slow down to the point where you've got dew on your eyepieces, camera lenses, the telescope . . . whatever's unlucky enough to be exposed to the night air.

Which brings us to one aggravating factor: the susceptibility of glass and metal to dew. Why is that?

The answer lies in the nature of glass and metal itself. Both are very efficient radiators of heat, and they give it away rather readily to the surrounding night air. Glass and metal do this so well that in no time they are cooler than the air touching them. When this happens, air layer that's immediately against the glass and metal slows down and condenses out its cache of water. And you're dewed out.

Knowing this, observers have put two and two together to formulate some simple countermeasures, ones that you can apply starting tonight. Assuming, of course, if it's clear.

Beat Back the Dew

Schmidt-Cassegrain telescope owners know that dew ranks way up there with mosquitoes when it comes to factors that can completely ruin an observing session. That's because SCTs, with their glass corrector plates exposed directly to the night air, are perfect radiators. The glass plate readily gives up heat, to which the air responds by gleefully giving up its water. What's an observer to do?

Well, build a barrier. If you could trap a layer of air above the corrector (or any lens surface, for that matter) that could absorb and provide insulation against some of the heat given off, maybe, just maybe, you could forestall the arrival of dew.

This is exactly what a dew cap does. The cap traps a column of air directly above the corrector plate. This in turn keeps the heat hemorrhage under control and sets up a buffer of warmer air that's less likely to give up its moisture to the glass.

Both Meade and Celestron offer dew caps to fit all the scopes they sell, as does the Orion Telescope Center and Kendrick Antidew Systems, who both market a dew shield that peels apart to lay flat for storage. You can even make your own dew cap by rolling up a piece of poster board and taping it into place.

Alas, a passive dew cap only puts off the inevitable. Air inside the dew cap slowly cools as night progresses. This lets the glass cool, as well as lets the air itself surrender the moisture it holds. One enterprising company, Roger W. Tuthill, Inc., markets a heated dew cap that keeps this from happening.

Staving off the dew blues might require you to take even greater measures along the lines of a heated dew cap.

Pull a Rope Trick

Many companies now offer heated ropes or straps that are powered by a battery. Wrap these straps around the edge of the optics and you'll solve the problem of them cooling off. Not only

An Arsenal of Dewmocracy

Passive Dew Shield

Heated Dew Shield

does this technique work for SCT owners, but also for owners of Newtonian and Dobsonian telescopes who have secondary mirrors that periodically fog up. (The primary mirror lies deep inside a dew shield of its own, at the bottom of a tube or shroud-lined network of trusses.)

It's important to note here that these ropes don't heat up glass appreciably. If such were the case, the telescope would be giving off so much heat that distortions from air turbulence would become visible in the eyepiece.

No, these dew fighters supply just enough heat to stave off rampant heat loss from the optics. If the night is particularly cool and damp, just dial up the heater's output to keep even the most tenacious dew attack under control. But even when the heater is going full-throttle, the optics are hardly warm to the touch.

Time for Hot Air

Heat ropes rarely succumb to dew, but when they do it's time to call out the big (dew) guns. Just as you would use a hair drier to dry your hair after a shower, so too could you use it to zap moisture from an optic.

Warm air put out by a blowdrier is more than eager to snatch up whatever moisture it runs into. If you have the luxury of outdoor AC outlets, a conventional blowdrier is more than up to the task.

If you're in the field and rely on a battery for power, then you'll not only have to use a drier that runs off DC power, but one that draws less power as well. Several astronomical suppliers sell DC driers that plug directly into a car's cigarette lighter. Check a local hardware store to see if they stock the same type of drier.

One word of warning, though. This accessory still draws a con-

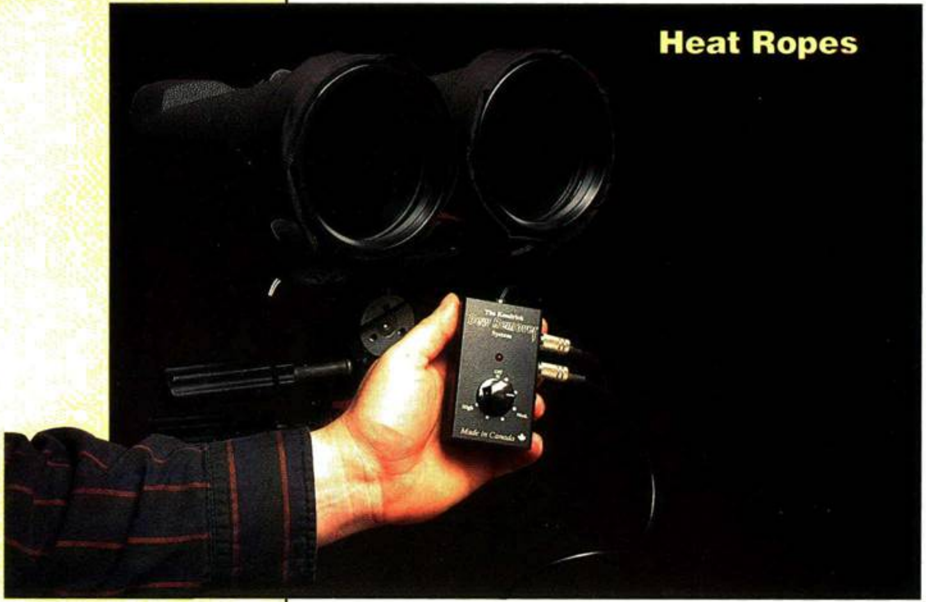
Your ability to combat dew runs from the passive all the way through the electrically active. Here's a survey of dew-fighting accessories and where to buy them:

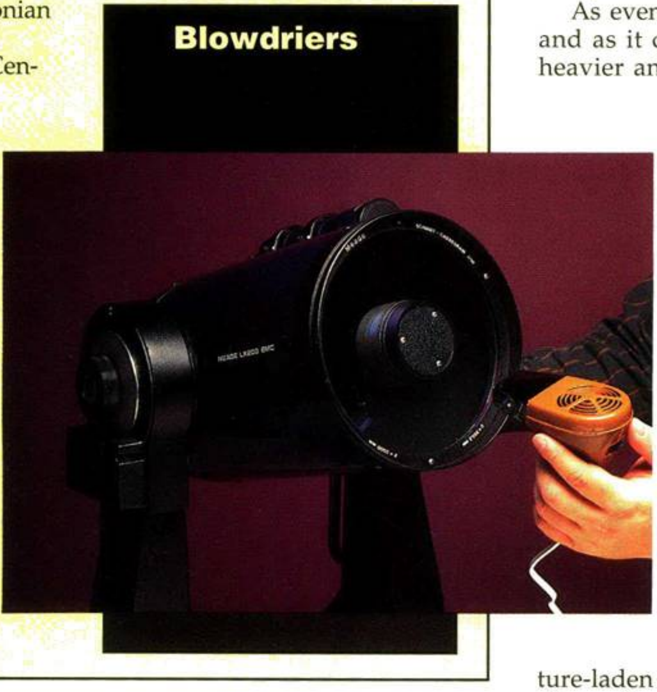
The passive dew shield. Sliding an open cylinder over an exposed lens or corrector plate creates a buffer between the cool night air and your optics. Schmidt-Cassegrain telescope manufacturers Celestron (310-328-9560) and Meade (714-756-2291) offer a line of rigid dew shields that fit their telescope line. Average price to equip an 8-inch SCT: $120. The Orion Telescope Center (408-464-0446) and Kendrick Anti-dew Systems (416-762-7946) sell flexible shields in a variety of sizes that peel apart and lay flat for storage. Average price to equip an 8-inch SCT: $50.

The heated dew shield. The No-Du Mark II heated dew cap by Roger W. Tuthill, Inc. (908-232-1786) uses heating elements to warm the air above the lens or optics. Price to equip an 8-inch SCT: $98.

Heat ropes. These strap along the edges of optics to keep glass from getting cold enough to attract dew. The initial purchase should include a control unit than can regulate the heat output of several ropes at once. Some suppliers offer kits to wire up finders, eyepieces, and Newtonian secondary mirrors. Suppliers include the Orion Telescope Center, Kendrick Anti-dew Systems, Dry-Eye Technologies (604-888-1505), and TW Engineering (714-527-2547). Average price to equip an 8-inch SCT: $50. (Include another $50 for a control until that regulates the heat coming from each heat rope.)

Blowdriers. Plugs into an outside electrical outlet or a 12-volt battery, like the one one pictured here from Orion (408-464-0446) that sells for $17.95. Also check your local hardware store for plug-in DC units.





siderable amount of current. If many electrical accessories are running off a car's battery, make doubly sure it's up to the job, or you may find yourself stranded come sunrise. If power comes from a portable battery, verify it provides at least 12 amp-hours of current. If all your electrical accessories run off of this one battery, you might consider building a "power box" that houses a deep-well, marine-type battery (see "Power To Go," January 1996).

Bring On the Fog

All this bristling electrical potential may make you feel invincible against dew — until the fog rolls in. Believe it or not, you can avoid this most insidious form of dew if you know where *not* to set up.

As evening progress, air cools, and as it cools, the cold air gets heavier and sinks into low-lying locations. Where the cold air settles, so, too, does dew. And if the air is really saturated with water vapor, fog forms.

Here is where a thorough understanding of your observing site's geography comes in handy. The logical answer to avoiding ground fog (and its attendant, heavy dew) is to set up on hillocks or rises. As the night cools down, the moisture-laden air will first settle into dips and valleys, buying you additional time (see the diagram on page 85).

Dew need not rear its ugly head ever again at any observing session. The right mix of hardware knowledge and topographical moxie goes a long way in keeping the dew blues at bay. Such savvy lets you get down to enjoying the sky and everything it has to offer — except the moisture. □

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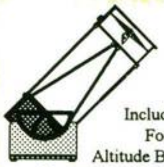

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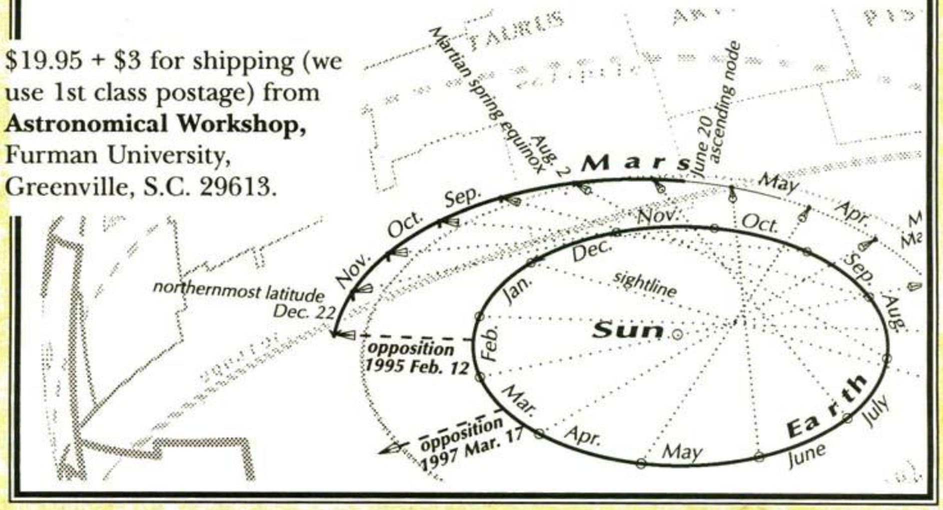

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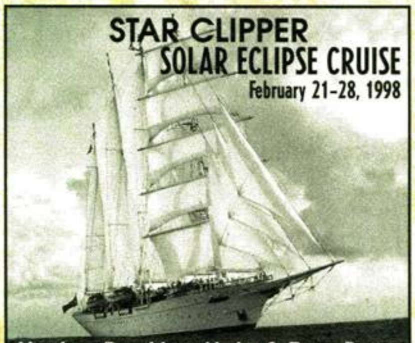

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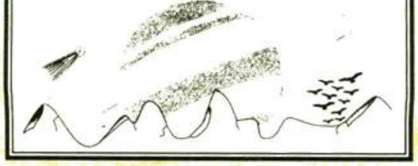

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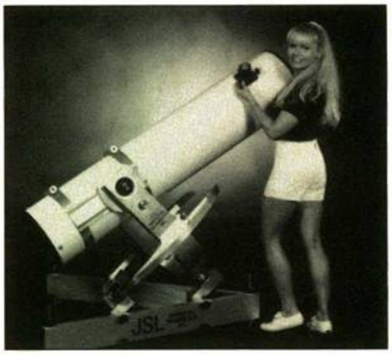

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Arthur C. Clarke's New Mars

The Snows of Olympus: A Garden on Mars
Arthur C. Clarke, (W. W. Norton & Co., 1995), ISBN 0-393-03911-0, 120 pages, hardcover, $25.

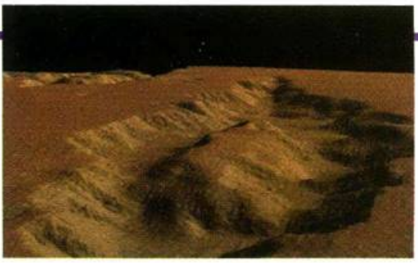
For more than 50 years, science fiction and science writer Arthur C. Clarke has bridged a gulf between technology and time. Clarke the futurist has an impressive track record of predicting what science has in store for humanity. In 1946 he foretold the development of communication satellites. Today a multitude of these spacecraft girdle Earth in a 22,000-mile-high Clarke Belt, relaying everything from HBO to real-time weather information directly to TV viewers in the comfort of their living rooms. And now that his global village has come to reality, Clarke looks still further into the future, to a time when there are two planet Earths: the one that we've come to know and love, and the other forged from the planet Mars.

The Snows of Olympus is Clarke's treatise on what may be humanity's most audacious undertaking in history, the not-so-gentle art of terraforming another planet into a new Earth. In typical Clarke style, it's a story that aptly weaves together science fact with science speculation.

The idea that Mars could someday resemble the Earth is hardly new. Its roots lie in a simple mistranslation of Giovanni Schiaparelli's 1877 Mars observations. The Italian astronomer's use of *canali* to described what he thought were merely streaks on the Martian surface (*canali* means "channel" in Italian) was translated into English as meaning "canals."

Thus began, to use Clarke's moniker, a Great Canal Delusion that gripped the imaginations of scientists and artists for more than 80 years. It inspired the science fiction of Edgar Rice Burroughs and H. G. Wells, and fueled the pseudo-science of Percival Lowell. Lowell claimed to observe a whole network of canals crisscrossing Mars, undoubtedly built by an intelligent race faced with extinction on an arid planet.

Such wild speculation made it easier for the scientific community to accept that while Mars may not harbor a race of sentient beings, it still just might have the right conditions to support simple plants (see "The Mars That Never Was," December 1995). Indeed, right up until the 1965 flyby of Mariner 4, which showed Mars to be a barren, Moon-like world, scientists held out hope that periodic changes in Mars' markings might be the result of plants flourishing and dying as seasons change.



But the Mariner 9 and Viking spacecraft have recast Mars as a complex world. The Mars of today sports dormant volcanos, a gigantic rift valley, and evidence of long-gone rivers, lakes, and seas. Clarke relates this aspect of the evolution of modern planetary science, reliving a personal journey. His roots in science fiction keeps the narrative lively and romantic while his grounding in science preserves intellectual vitality.

Today we know the Red Planet has more in common with Earth than any other planet. That, coupled with its proximity, makes it a logical target for human exploration. Clarke sees Mars as a stepping-stone into the cosmos. Again, through the combination of science fiction and fact, Clarke explains how we might get there and eventually set up a permanently manned base.

But after that, what?

Well, there's terraforming. The book is not so much how we might do it (through redirecting comets to smash into the planet's surface or the subtle machinations of self-replicating robots) and how long it would take (many centuries) as it is about how a terraformed Mars might look. Therein lies the core of *Snows of Olympus*.

Clarke employs the wonders of desktop computer simulation, and fully explores how three regions of Mars might change over time from the introduction of lichens to the planting of forests. The graphics he generates using Vistapro 1.0 software give the reader plausible renderings of how the volcano Olympus Mons, the rift valley Valles Marineris, and the riverbed network of Labyrinthus Noctis might gently make their transition from stark Martian wasteland into what could pass for as a carbon copy of the American desert Southwest.

All this God-play might raise a few eyebrows, so following the splashy terraforming-simulation sections is a chapter in which Clarke explores man's seeming "manifest destiny" not only as it might apply to terraforming, but to space exploration in general. And that's what Clarke does best: balance the real with the probable as a way of exploring the fantastic. Through *Snows of Olympus*, we witness humanity's evolving picture of Mars and have a glimpse into what could be the Red Planet's, and our, destiny. — *John Shibley*

(Browse the first chapter and table of contents of The Snows of Olympus *and other recently reviewed books on the Internet at: http://dab.psi.net/chapterone/astronomy)*

More New Books

The Secret Melody: And Man Created the Universe

Trinh Xuan Thuan (Oxford University Press, 1995), ISBN 0-19-507370-3, 313 pages, hardback, $25.00.

Did the universe come about by accident or design, and if it's the latter, who created it? These are just some of the weighty issues that Trinh Xuan Thuan grapples with in this book. The author, a University of Virginia astronomer, is known as "the French Carl Sagan." *The Secret Melody* was in fact originally written in French, and it was a best-seller in France. The book was translated into English and later updated by Trinh.

The first half of the book is a primer on how humanity's vision of the universe has changed, from the Sun-centered cosmos of the ancients to the big bang cosmology of today. The second half is devoted to the modern scientific view of the universe. Trinh likens the universe to a distant orchestra that plays fragments of a symphony. But we can't quite hear the entire symphony, there are missing notes. Science's job is to fill in the gaps, so the secret melody shines through in all its glory.

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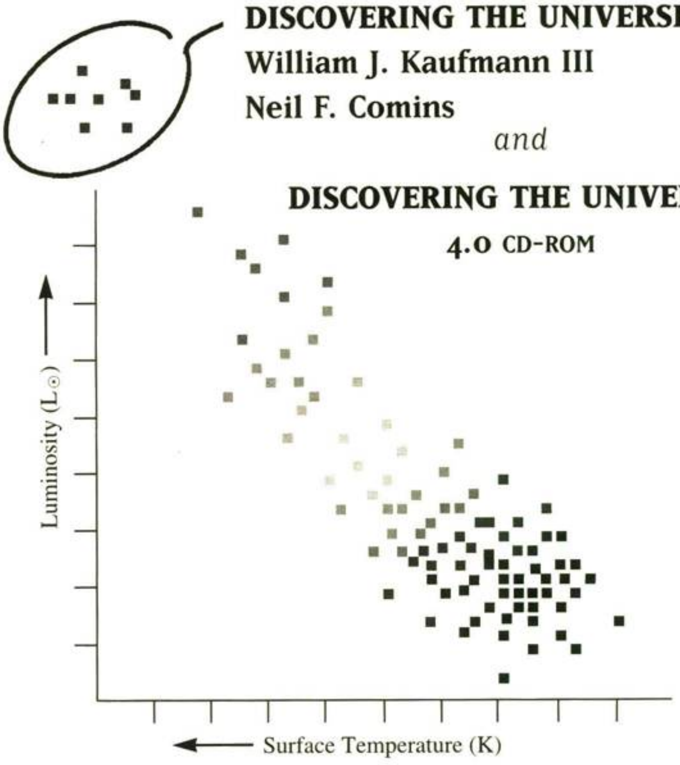

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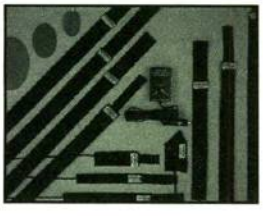

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BOOKS

Later chapters surpass the realm of science, discussing issues that often lie within the domain of theologians and philosophers. Trinh concludes that the scientific evidence points toward a universe in which the physical laws have been fine-tuned to enable life to exist, an idea called the anthropic principle.

Readers will encounter a text that is much more densely packed with hard science than a typical Carl Sagan book, and the work lacks color photos and illustrations. Nevertheless, the science is clearly explained and the discussion is eloquent and thought-provoking.

Impact Jupiter: The Crash of Comet Shoemaker-Levy 9

David H. Levy (Plenum Press, 1995), ISBN 0-306-45088-7, 290 pages, hardback, $25.95.

David H. Levy, renowned observer and co-discoverer of Comet Shoemaker-Levy 9, has written this lively, largely first-hand account of the 1994 Jupiter comet impact. The book is written as a collection of stories. The early chapters recount the discovery of the comet, the realization that it had split apart during a 1992 close encounter with Jupiter, and the subsequent revelation that it would smash into the planet in July 1994. In the final chapters, Levy covers the history and science of comets in general and the impact of Shoemaker-Levy 9.

Although this book is not as tightly organized as the shorter and more formal Cambridge University Press book *The Great Comet Crash* (see AstroBooks, November 1995), it puts the reader right at the center of action. Readers are given the inside scoop into the scientific discussions and debates that took place before the impact, before anyone knew for sure whether it would be an awesome spectacle or a fizzle. The book builds suspense up to impact week, and then describes the impact of each fragment. Levy presents the science in short, easily digestible bits.

This book is nowhere near as lavishly sprinkled with photos as *The Great Comet Crash*. Nevertheless, for those willing to spend more time with a narrative account, *Impact Jupiter* is a great read that provides an insightful look into the world of science. □

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Type A & B are for unlimited visual use and general photographic use. Instructions, including tips on solar photography are included with all filters.

GLASS — Type C (Red Label)
Coated to a neutral density of 4 for maintaining fast shutter speeds when using slow films. Solar image and optical quality same as Type A & Type B. Type C filters are for photographic use only. Transmission is 1/100th of 1%.

APERTURE	GLASS A	GLASS B	GLASS C
2.4"	52.00	38.00	69.00
3.1"	55.00	42.00	74.00
3.5"-4.5"	65.00	49.00	95.00
5.0"	85.00	62.00	109.00
6.0"-7.0"	92.00	67.00	119.00
8.0"-10.0"	112.00	92.00	139.00
11"	139.00	99.00	159.00
12"-13.1"	159.00	119.00	179.00
14"	179.00	139.00	199.00
BINOCULARS			
40-80MM	99.00	79.00	n/a

Unmounted filters for custom applications are $14.00 less than prices listed above.

PRICE GUARANTEE: If you find a lower price on any competitive brand of glass solar filter, simply note the brand and we'll automatically match it.

ORDERING INFORMATION
Solar View filters are shipped free in continental U.S. Please specify telescope brand and/or outside diameter measurement of telescope tube.

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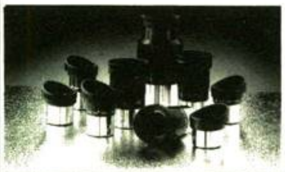

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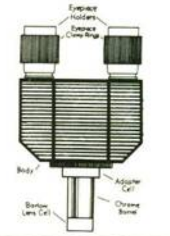

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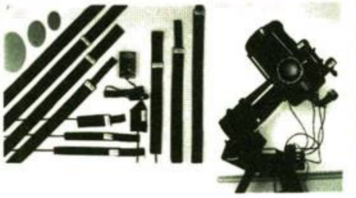

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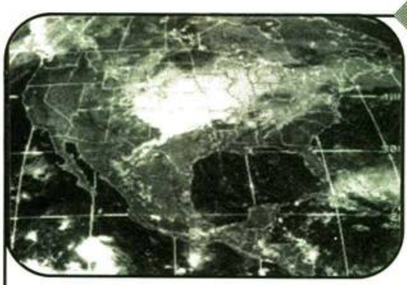

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For further information, write to: Midwest Light Pollution Conference, W248 S7040 Sugar Maple Drive, Waukesha, WI 53186, or e-mail: dkoehler@astronomy.com.

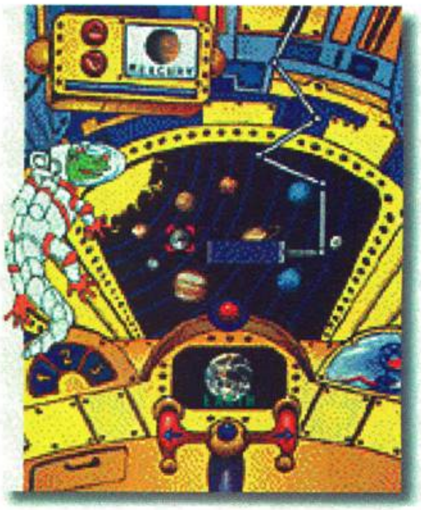
ASTRO BYTES

New Software Roundup

The Magic School Bus Explores the Solar System

Microsoft Corporation, direct order at (800) 457-9530 or see your local computer store; for deaf or hard-of-hearing phone service, call (800) 892-5234. Price: $49.95; $69.95 in Canada. Minimum requirements: Multimedia PC with a 486SX microprocessor, 4 MB of memory, 5 MB of free space on a hard drive, double-speed CD-ROM drive, 8-bit audio board and speakers or headphones, mouse, SVGA display capable of 256 colors, DOS 5.0, and Windows 3.1.

Scholastic's Magic School Bus takes off into space, bringing the wonders of the solar system to children ages six through ten. Ms. Frizzle and her class, from the books created by Joanna Cole and Bruce Degen, jump in their school bus to go to the local planetarium. On the way, the bus morphs into a rocket ship that blasts into space. Somehow during liftoff the teacher gets lost.



The students need the user's help to search ten planets and moons to find Ms. Frizzle. Clues abound such as reports on each planet. Clicking on one of the student's sketch pad enables the user to participate in science experiments (nine in all) to gain clues. The class's pet lizard is usually lurking around the screen to offer help. Nine games offer chances to win tokens that can be exchanged for more clues.

Installation is easy so kids can do it themselves. The user manual is also a passport. As a child explores a planet or reaches other milestones in the game, he or she can paste stamps into the book. The pages also contain space for listing clues, writing notes, or drawing pictures about each planet.

Meridian

Claude Duplessis, 104 Rang Ste-Catherine, Yamaska, QU J0G 1X0, Canada, e-mail claude_d@mksinfo.qc.ca. Shareware price:$25. Minimum requirements: IBM PC-compatible computer, Windows 3.1, and an EGA monitor.

The *Central Meridian of Mars* (see AstroBytes, November 1995) has been upgraded to include information about Jupiter. Now called *Meridian,* it maintains the trilingual set of instructions as it plots the position of the planet in the sky, shows its size compared to the minimum and maximum values it can reach, lists satellite phenomena such as eclipses, plots the positions of the satellites, and shows the position of the Red Spot. An information table lists distance from Earth and System I and II longitudes, as well as the planet's position, diameter, and brightness.

Computing Newsletter

Using commercially available programs doesn't satisfy every computer user. Many enjoy creating their own programs in BASIC or another computer language to solve problems that aren't treated by other software. An informal newsletter that caters to folks who like writing and debugging programs is *The Orrery*. Produced by Caxton Foster (P.O. Box 488, East Orleans, MA 02643), the newsletter costs $5 for six issues ($10 overseas), which appear over the course of about a year.

The last few issues included articles about tides, motions in star clusters, faster-than-light motion of gas in jets emanating from galaxies, spaceflight to the Moon, and the stability of asteroid orbits near Jupiter. Every issue contains several BASIC programs so readers can study an astronomical concept and not just read about it. Foster encourages subscribers to contribute to the newsletter and share their results from running certain programs. ☐

Software developers may send new programs and upgrades to AstroBytes, Astronomy Magazine, P.O. Box 1612, Waukesha, WI 53187-1612 or e-mail bytes@astronomy.com. Check out Astronomy's home page at **http://www.kalmbach.com/astro/astronomy.html**.

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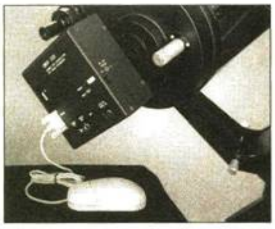
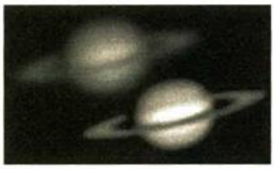


CWIP S shown with mouse.
No computer is required.

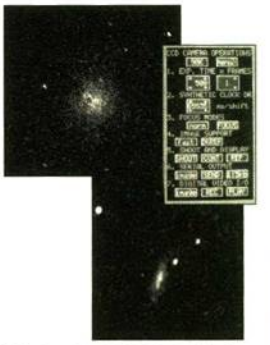
Are You Equipped?
Imagine producing more results than entire astronomy clubs, crowding walls with stunning images which are enhanced and printed exactly the way you want them. Next, imagine paying much less than you would for film, accessories and the telescope upgrades you'd need for such an ambitious program. You've just been thinking about a SIRIUS INSTRUMENTS CWIP CCD.



Saturn, before and after enhancement.
Pale cloud bands snap into view

CWIP CCD's combine the functions of all-digital ambient CCD Camera with Workstation for Image Processing, two key ingredients to successful images. Some CCD chips saturate at room temperature during readout, even with zero exposure time, making ambient operation impossible whereas the Sanyo LC9931 allows a minute per exposure at room temperature. While thermal charge accumulates more quickly than in cooled cameras, thermal noise accumulates only by the square root, resulting in extraordinary sensitivity with this impressive imaging chip. Precise dark frame calibration increases sensitivity 10-fold, much more than cooled 8-bit cameras, and multiple exposure summation takes sensitivity well beyond single exposure levels.

NGC5139 90mm f/4, 2x25 seconds with *SCD*

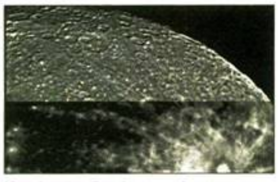


M82 otherwise invisible in badly light polluted skies. 90mm f/4 with *SCD*

Synthetic Clock Drive (SCD)
Use any optics! Most telescope drive systems are not precise enough for prolonged time exposures without expensive upgrades. CWIP CCD's offer two solutions: *Synthetic Clock Drive* allows you to turn your motors off and use as non-motorized scopes or lenses. By dialing in a shift rate, *SCD* electronically shifts the accumulating image at the drift rate of stars and other objects crossing the CCD chip. Or if your telescope has a moderately stable drive, shoot short time exposures. Either way, use flash alignment and summation to combine individual exposures for substantially more sensitivity. Image de-rotation software allows combining multiple exposures from altazimuth mounted scopes and lenses.

Model Comparison
CWIP-10's 10 bit A to D converter is 4X more sensitive than 8 bits. Pixel resolution is nearly triple that of comparably priced cameras. With full featured software, not a mini-version. The CWIP-10 is upgradable to any other model.
The CWIP-12's 12 bit A to D converter is approximately twice as sensitive as the CWIP-10 for the same exposure time.
CWIP Camera/Autoguider models offer the most interactive visual feedback to set up the autoguider and to diagnose and prevent autoguiding problems early. Autoguider capable telescope required.

Only the advanced CWIP-S can capture, store and process images without ever needing a computer. The video output displays control panels easily operated in the dark with a mouse (provided). Digital videotape data storage and retrieval uses a camcorder or VCR like a hard drive... for unlimited storage of redundant, reliable image data. Serial cable included.
All models include 1.25" eyepiece adapter, 2-way power and our fast, interactive PC software packed with useful features.



Moon image, split and processed two ways
(10" Newtonian with f/2 reducer and aperture)

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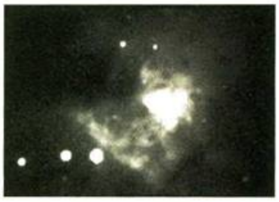
CCD type: Sanyo LC9931 ambient frame transfer type. Resolution: 378h x 240v. CCD size: 1/3 inch diagonal. 12 bit sensitivity in 20 seconds exceeds: 9th magnitude (90mm scope),12th mag (8-inch),15th mag (16 inch).



M42 in Orion, 4 x 4 seconds, 8" f/10

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NEW PRODUCTS

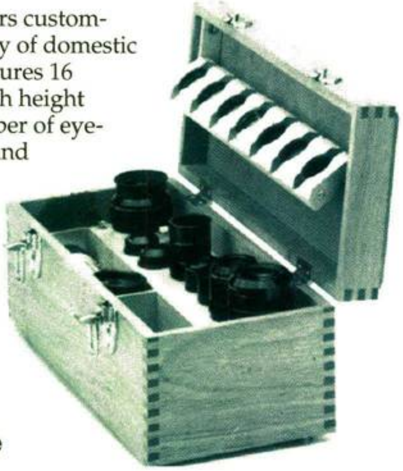
SkyView Reflecting Telescope

Orion Telescope Center's SkyView 4.5 is a beefy 4½-inch f/8 reflecting telescope sold with an adjustable aluminum tripod and German equatorial head. A fully-aluminized primary mirror sits in an adjustable cell for easy collimation and the secondary mirror rides in a fully adjustable, four-vane spider mount. The telescope's enamel-coated aluminum tube is fitted with a 6x30 finder mounted in adjustable rings and a 1¼-inch rack-and-pinion focuser. SkyView's German equatorial mount has slow-motion controls with large knobs that you adjust to follow the sky. An optional clock drive motor tracks the sky automatically. Nested on spreaders between the tripod legs is an eyepiece tray. SkyView 4.5 comes with two fully coated Kellner eyepieces, a 25mm and 9mm that yield 35x and 100x, respectively.

Orion Telescope Center, 2450 17th Avenue, P.O. Box 1158, Santa Cruz, CA 95061. (408) 464-5710. SkyView 4.5 Reflector (item # 9071): $399; 110V Motor Drive (item # 7295): $99.

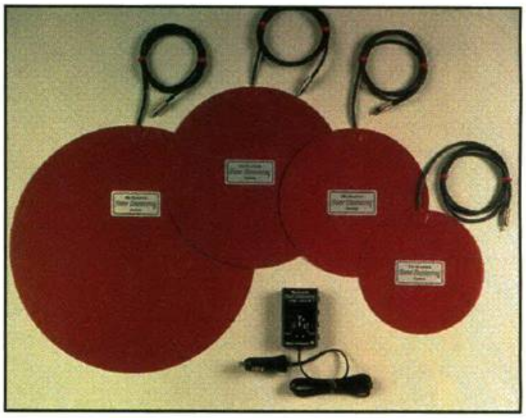
Custom Accessory Box

Woodworker Steve Johnson offers custom-made accessory boxes from a variety of domestic hardwoods. His standard box measures 16 inches wide by 6½ inches deep, with height depending upon the type and number of eyepieces you want stored. Eyepieces and other accessories stow in a lower level, while 1¼-inch or 2-inch filters slide into a fold-up filter tray in the lid. The box's interior is lined with suede-tex velour. Larger boxes with stepped shelves are also available.



Johnson Woodworking, 4107 57th Street, Des Moines, IA 50310. (515) 270-9581. Standard Eyepiece Storage Box: $150.

New Products presents announcements issued by manufacturers. ASTRONOMY assumes no responsibility for the product information supplied. Prices are suggested retail. Suppliers should send announcements and color photographs to the attention of John Shibley, P.O. Box 1612, Waukesha, WI 53187, or newprod@astronomy.com.



Primary Mirror Heaters

Kendrick Dew Remover System has expanded their line of heaters to include a pad that presses against the back of a primary mirror. Kendrick suggests applying the pad with a thin coating of silicone. Each pad plugs into a controller sold separately and fends off dew by gently heating up the mirror 1° to 2° above ambient temperature without distorting the optic's figure. The redesigned controller now produces no radio frequency interference, which can degrade a CCD camera's performance. Pads come in 8, 10, 12, and 16 inch diameters.

Jim Kendrick Studio, 2775 Dundas Street West, Toronto, Ontario, Canada, M6P 1Y4. (416) 762-7946; fax, (416) 767-4112. P8 heater pad for 8-inch mirrors: $40 US; P10 for 10-inch mirrors: $55 US; P12: $75 US; P16 (fits up to a 20-inch mirror): $129 US. Heater controller: $60 US.

Star Chart Case

The Star Gazer Chart Carrier has pockets that store chart pages from the *Sky Atlas 2000.0* field or desk editions. The carrier is made of water-resistant cordura and has a poly-web carrying handle sewn into its top. For field use, the carrier opens up and lays flat. Charts are visible through vinyl pockets that can be written on with an erasable marker. Chart Carrier comes in navy blue, and can be sized to order.

Rhondele's Excess Baggage, 955 N. Main, Buffalo, WY 82834. (307) 684-5152. Star Gazing Chart Carrier: $13.95, plus $3.50 shipping and handling. Visa, Master Card, and cashier's check accepted.

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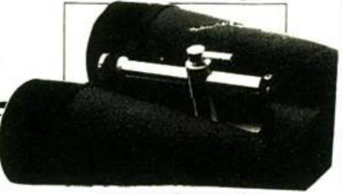

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Products

Improved Reflex Finder

Rigel Systems has made its Quikfinder reflex sight both lighter and smaller. The redesigned finder projects a ring of light onto a piece of Plexiglas you sight the sky through. The projected ring covers 2° of sky when viewed from about two feet behind the finder. Three calibration thumb knobs center the ring with the telescope's field of view, after which the finder is used to aim the scope at other targets. Quikfinder stands 4" above a mounting baseplate that measures 1¾" square. The finder's gray PVC housing holds an LED light source that is powered by one 3-volt lithium battery. Each reflex sight comes with a baseplate and battery.

Rigel Systems, 26850 Basswood Ave., Rancho Palos Verdes, CA 90275. Voice/fax, (310) 375-4149. Quikfinder Reflex Sight: $39.95, plus $4.95 shipping; extra baseplate: $7, plus $2.95 shipping; extra battery: $1, plus $1 shipping.

Sun Poster

Learn about our Sun with this new poster from the Hansen Planetarium. The 22½-inch by 29-inch poster is dominated by an oversized drawing of the Sun that shows features visible in white light, including sunspots, granules, and flares. Planets of the solar system arranged in one corner convey the Sun's relative size. An adjoining cutaway details and explains the Sun's five layers. Another box illustrates how its magnetic field drives the features we see and effects the corona, a tenuous, outer solar atmosphere. A series of panels lay out how our Sun formed from a nebula 4½ billion years ago. Statistics such as size, temperature, and luminosity are presented in a data table. The poster comes shipped rolled in a tube.

Hansen Planetarium Publications, 1845 South 300 West, #A, Salt Lake City, UT 84115-1804. (801) 483-5400; fax, (801) 483-5484. Sun poster on paper: (stock # 50-7): $6; laminated (stock # 9050-7): $11.50.

Astronomical Organizer

The *1996 Sky Planner* system divides itself into six sections: a sky calendar, an observer's log, a technical section, sky charts, a glossary, and a directory. Each page in the sky calendar section corresponds to a week, and provides universal dates and times for upcoming sky events. Important dates in astronomy and space travel are also noted. A plastic page divider explains how to convert UT into local time.

The observer's log breaks out important sky events by month, and leaves space to add unexpected events. This section also includes sunset, sunrise, and twilight times for latitudes between 20° and 60°. Record sheets let the observer plan targets and note seeing conditions by circling limiting star magnitudes on a circumpolar constellation map printed on each page.

The technical section features a telescope reference sheet, a filter guide, and sheets for deep-sky and planetary drawing. Astrophotography sheets record such details like the film and lens used.

The sky charts section is a complete sky atlas down to 5th-magnitude, and shows popular double stars and deep-sky objects, including the Messier list and brighter NGC objects. Following this section is a 16-page glossary of astronomical terms, and a directory that lets you fill in important addresses and phone numbers.

Sky Planner Enterprises, 2336 West 5650 South, Roy, UT 84067. (801) 825-9239. Elite Planner System with zipper (shown): $69.95; Planner System even-ring binder; $59.95; Sky Planner System, sheets only: $42.95.

Music of SETI

SETI: Pharos is a unique two-compact disk set that blends the sounds of radio signals captured during NASA's Search for Extraterrestrial Intelligence program (SETI) with evocative and abstract space music. Interspersed between mosaic of sound and music are comments by SETI's program manager Frank Drake. An illustrated 20-page booklet holds explanations of the SETI program and the signals it detected, as well as many photos.

Instinct Records, 26 West 17th Street #502, New York, NY 10011. (212) 727-1360; fax, (212) 366-5979. SETI: Pharos (item # AMB-001-2): $16.95.

Apollo 12 Comic Book

Moon Shot: The Flight of Apollo 12 is a 40-page educational comic book that recounts the November 1969 flight of Apollo 12 through the eyes of astronaut Alan Bean. Color panels follow Bean through training and culminate with his lunar mission. Other sections contain a glossary of space terms, an explanation of how the spacecraft worked, plus interviews with a lunar geologist and Bean's Apollo crewmates.

Pepper Pike Graphix, 6657 Vista Del Mar, Suite A, Playa Del Rey, CA 90293. (310) 306-7614. $2.95.

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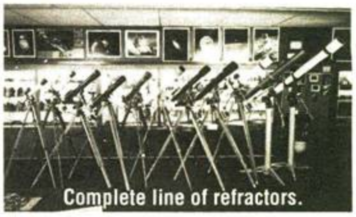
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RESOURCES & PHOTOFACTS

Lone Star Infants (page 36)

"Encounters in Orion," by Ken Croswell, ASTRONOMY, January 1992. A double star in the Orion Nebula provides insight into how binary stars form and how they escape their birthplace.

Stars, by James Kaler (Scientific American Library, 1992). A popular-level discussion of stars and stellar evolution.

The Remarkable Odyssey of Jane Luu (page 46)

Planets Beyond: Discovering the Outer Solar System, by Mark Littmann (John Wiley & Sons, Inc., 1990). Gives historical context to the discovery of the outer planets and other objects as well as highlighting modern events, such as Voyager 2's grand tour, that are moving astronomers into the future.

Of Wormholes, Time Machines, and Paradoxes (page 52)

Black Holes & Time Warps: Einstein's Outrageous Legacy, by Kip S. Thorne (W. W. Norton & Company, 1994). By tugging on one historical thread, this award-winning book unravels the complexities of black holes, singularities, gravtiational waves, worm holes, and time warps. Exposes scientists and nonscientists to the areas of physics, astronomy, philosophy of science, sociology of science, politics of science.

"Tunnels Through Time," by Barry Parker, ASTRONOMY June 1992. Discusses the possibilites of traveling through time and what one would experience during the ride.

Come-As-You-Are Photography (page 74)

Astrophotography for the Amateur, by Michael Covington, (Cambridge University Press, 1985). Presents a thorough overview of astrophotography techniques.

Beat Back the Dew Blues (page 84)

The Weather Book, by Jack Williams, (Vintage Books, 1992). A illustrated and easy-to-understand explanation of weather by the staff of *USA Today*.

"Transform a Bucket into a Dewcap," by Joseph Kempter, ASTRONOMY, November 1993. Another creative way to roll away the dew.

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pp. 44-45: Luke Dodd, 4.7-inch f/8.5 refractor, hypered Fujicolor 400, ST-4 autoguider, two stacked exposures, 75 minutes and 90 minutes; **p. 74:** Larry Landolfi, sunrise in Herchsher State Park, 50mm lens set to f/8, 1 second foreground exposure, Sun every 6 minutes through Sun-dot filter, Ektachrome 200 slide film; **p. 75:** L. Landolfi, polar star trail pictures; 35mm and 50mm lenses set to f/4, 45 minutes, Ektachrome 200 slide film; **p. 76:** L. Landolfi, sunset over Manhattan, 50mm lens set to f/8, 1 second foreground exposure, Sun every 6 minutes through Sun-dot filter, Ektachrome 200 slide film; **p. 77, top:** L. Landolfi, sunset over Long Island Sound, 50mm lens set to f/8, 1 second foreground exposure, Sun every 6 minutes through Sun-dot filter, Ektachrome 200 slide film; **p. 78:** L. Landolfi, moonrise over Robert Moses Bridge, 500mm f/5.6 lens, 1/125 second, Ektachrome 200 slide film; **p. 78, top:** L. Landolfi, moonrise over Fire Island lighthouse, 500mm f/5.6 lens, 1/125 second, Ektachrome 200 slide film; **bottom:** L. Landolfi, "patriotic moonrise" past Vietnam Veterans Memorial in Farmingdale, N.Y., 35mm lens set to f/8, foreground exposure 1/125 second, Moon exposures 1/30 second through color filters every 2½ minutes, Ektachrome 200 slide film; **p. 111, top:** Dan Schechter and Ronald Royer, 18-inch f/7 reflector, hypersensitized Ektachrome P1600 developed at ISO 800, 15-minute exposure taken September 22, 1995; **bottom left:** Michael Stecker, 5-inch f/6 refractor, hypersensitized Fujicolor 800 film, 40-minute exposure taken September 2, 1995; **bottom right:** Gerald Rhemann and Franz Kersche, 8-inch f/1.5 Schmidt camera, hypersensitized Ektar 25 film, 96-minute exposure taken July 5, 1995; **p. 112, top left:** Franz Kufer, 28mm lens at f/6.7, ScotchChrome 400 film, 30-minute exposure; **top right:** Alberto Levy, 3-inch refractor at f/21, Fujicolor 160 film, shot from Sariska, India; **middle:** James R. Foster, composite of four filtered exposures shot with a 14-inch SCT at f/7 and two filtered exposures shot with an 11-inch SCT at f/6. Total exposure time was 13.2 hours; **bottom:** Martin C. Germano, 14.5-inch f/5 reflector, hypersensitized Tech Pan film, 75-minute exposure; **p. 113:** Alverto Levy, composite made with a 50 mm lens on October 24, 1995, from Sariska, India; ***p. 114:*** *Franz Kufer*, 7-inch refractor at f/34, ScotchChrome 100 film, 1/8-second exposure. □

MEETINGS & EVENTS

January 27-February 2
Photonics West '96 Symposium, San Jose, California. Sponsored by the International Society for Optical Engineering. Contact SPIE, P.O. Box 10, Bellingham, WA 98227, (360) 676-3290.

February 3-4
Northwoods Winter Starfest, Fall Creek, Wisconsin. Sponsored by the Chippewa Valley Astronomical Society. Contact Ray Forsgren, 4856 Inlet Drive, Chippewa Falls, WI 54729.

February 8-13
AAAS Meeting, Baltimore, Maryland. Sponsored by the American Association for the Advancement of Science. Contact the AAAS Meeting Office, 1333 H Street, N.W., Washington, DC 20005, (202) 326-6450, or amsie96@aaas.org.

February 12-18
Winter Star Party, near Key West, Florida. Sponsored by the Southern Cross Astronomical Society. Contact Bob or Sharon Grant, 5401 SW 110 Avenue, Miami, FL 33165, (305) 595-8778.

February 15-18
The Orange Blossom Special, near Brooksville, Florida. Sponsored by the St. Petersburg Astronomy Club, Inc. Contact Dennis and Ellen Farr, 8811 West Broad Street, Tampa, FL 33615, (813) 884-9111.

February 24
Wagman Winterfest, near Russellton, Pennsylvania. Sponsored by the Amateur Astronomers Association of Pittsburgh. Contact the AAAP at Wagman Observatory, (412) 224-2510.

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Smart Structures and Materials Symposium, San Diego, California. Sponsored by the International Society for Optical Engineering. Contact SPIE, P.O. Box 10, Bellingham, WA 98227-0010, (360) 676-3290, spie@spie.org.

March 17-20
Visual Communications and Image Processing, Orlando, Florida. Contact SPIE, P.O. Box 10, Bellingham, WA 98227-0010, (360) 676-3290.

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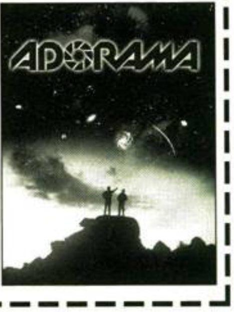

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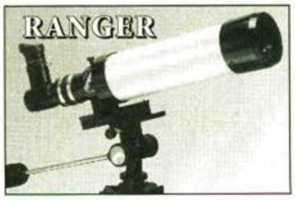

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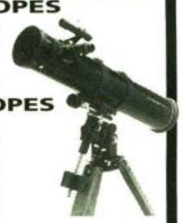

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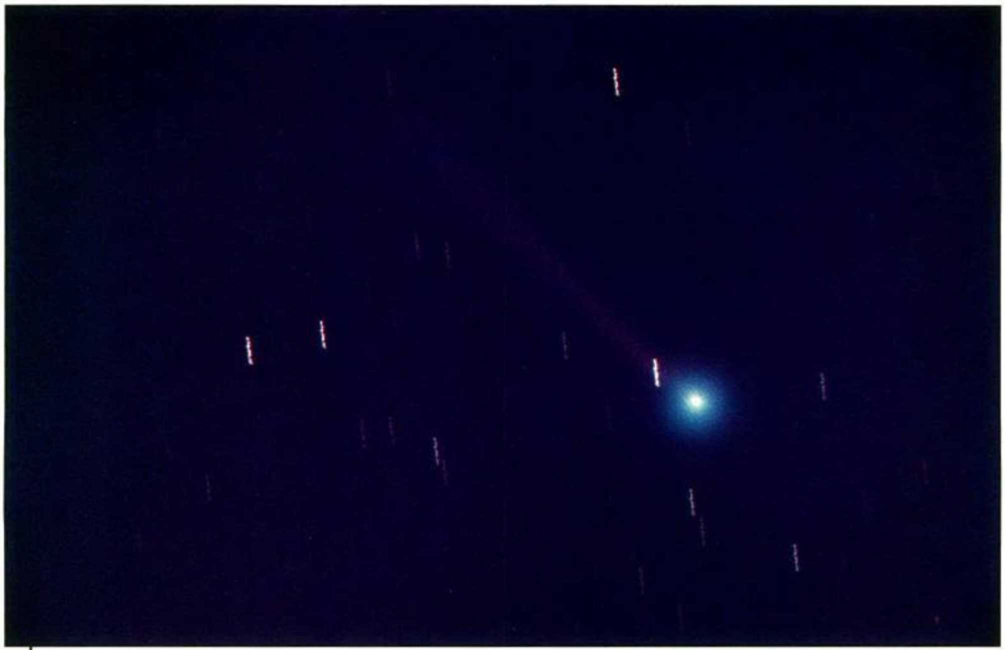
Night of the Six Comets

"My buddies and I did something really challenging," says Tom Johnston of Boulder, Colorado. "From a remote site near Vail, we spotted six comets in a single night." Bob Ross, Kurt Van Derhorst, Dave Young, and Johnston set out to bag as many as they could.

It was early October 1995. First, the Coloradoans pegged Comet Schwassman-Wachmann 3, which had undergone an outburst and surprisingly approached naked-eye brightness rather than glowing at its typically meek maximum of 10th magnitude. Next on the agenda, the group located the much anticipated Comet Hale-Bopp. "I managed to find it near the spout of the Sagittarius teapot," says Johnston. "As of that night, it wasn't much to look at, but just wait until 1997!"

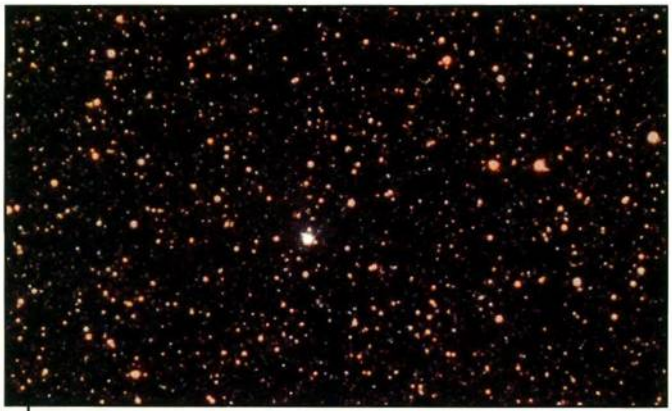
Ross used his 36-inch scope to spot elusive Comet Clark, a faint object located in Microscopium. "This was the smallest, faintest comet I've ever looked at," Johnston says. Soon thereafter, Johnston located Comet D'Arrest, which was visible but flirting with the southern horizon. Next, the observers honed in on the recently recovered Comet De Vico, "the best comet I've seen since Levy (1990c) in 1990," according to Johnston. The comet displayed a large, bright coma and an intense core with a pinpoint nucleus. The comet also sported a narrow, patchy tail over a degree long.

By now most of the night had ebbed away. As dawn approached, Johnston swept through the dusky blue low on the horizon and found



Comet De Vico

by Dan Schechter and Ronald Royer
(18-inch f/7 reflector, hypersensitized Ektachrome P1600 developed at ISO 800, 15-minute exposure taken September 22, 1995)



Comet Hale-Bopp

by Michael Stecker
(5-inch f/6 refractor, hypersensitized Fujicolor 800 film, 40-minute exposure taken September 2, 1995)

Comet D'Arrest

by Gerald Rhemann and Franz Kersche
(8-inch f/1.5 Schmidt camera, hypersensitized Ektar 25 film, 96-minute exposure taken July 5, 1995)

Comet Bradfield. "It would have been invisible 10 minutes later," says Johnston, relieved at the accomplishment. Could life possibly get any better?

Comet De Vico. "This beautiful comet shows an intricately detailed structure in a 4-inch refractor at 27x," remarks Chris Spratt of Victoria, British Columbia. "The tail stretched over 1.5° and had a delicate, uneven, split-fork structure at the head where the plasma tail separates." Spratt observed it on September 24 and October 1, 1995. The coma measured about 6', says Spratt, and it had an asymmetric center.

Richard R. Didick of Rehoboth, Massachusetts, found the comet's center "bright, diffuse, and with a central condensation."

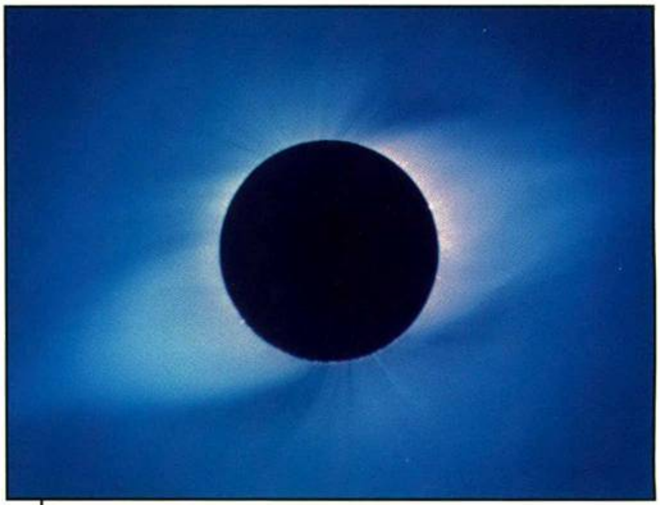
Peculiar Bolide Meteor Train. While observing from a dark-sky site in the Sierra Nevada mountains, David Hasenauer of Pasadena, California, spotted an unusual meteor train. "I was looking at a star chart and like a camera flash, the surroundings lit up," he reports. The observation occurred on September 24, 1995, at about 10:20 UT. The meteor train appeared about 3° southwest of the Pleiades.

"I looked up to see an odd train that first appeared as a circular green patch of light, with two parallel trails extending from it. The trails were about 20' apart and were visible for about 10 minutes," he says. Hasenauer observed the train with a telescope and saw the complex drift about 2° to 3° before fading into the sky background. □

ASTRONOMY wants to hear about your observations of the sky. Send reports, sketches, photographs, and disks to David J. Eicher, Reader Reports Editor, ASTRONOMY, P.O. Box 1612, Waukesha, WI 53187-1612. Please label each photo with name, address, and social security number. You may send written reports via the Internet to: rreports@astronomy.com

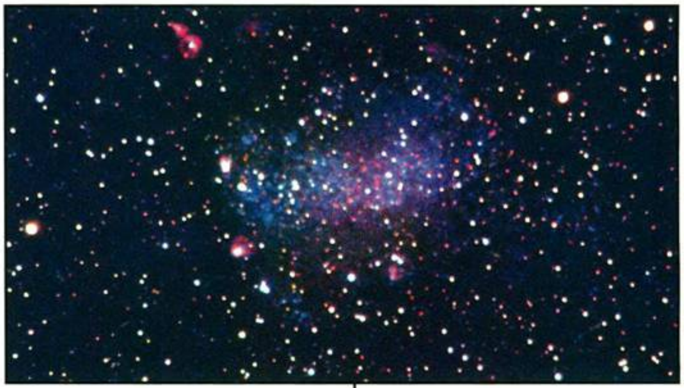
The Magellanic Clouds

by Franz Kufer
(28mm lens at f/6.7, ScotchChrome 400 film, 30-minute exposure)



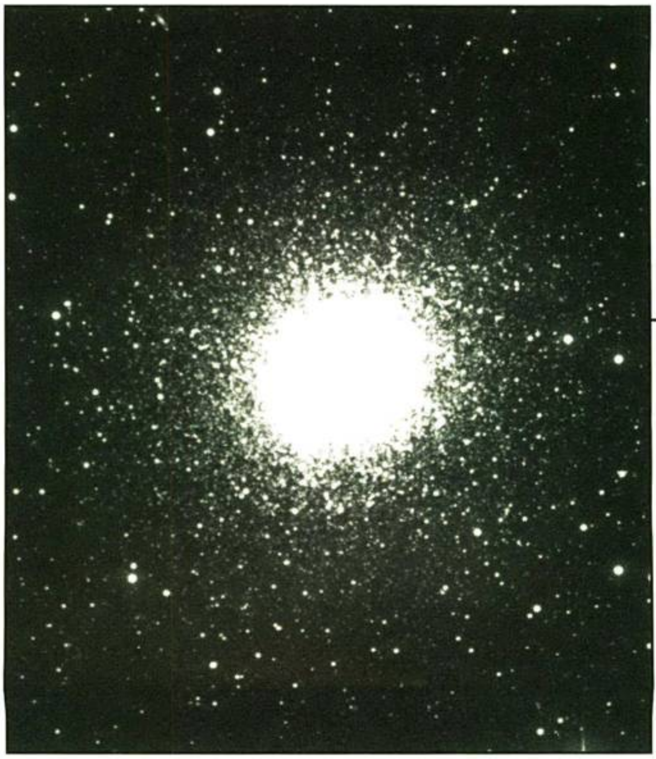
Solar Eclipse on October 24, 1995

by Alberto Levy
(3-inch refractor at f/21, Fujicolor 160 film, shot from Sariska, India)



Barnard's Galaxy (NGC 6822)

by James R. Foster
(composite of four filtered exposures shot with a 14-inch SCT at f/7 and two filtered exposures shot with an 11-inch SCT at f/6. Total exposure time was 13.2 hours)

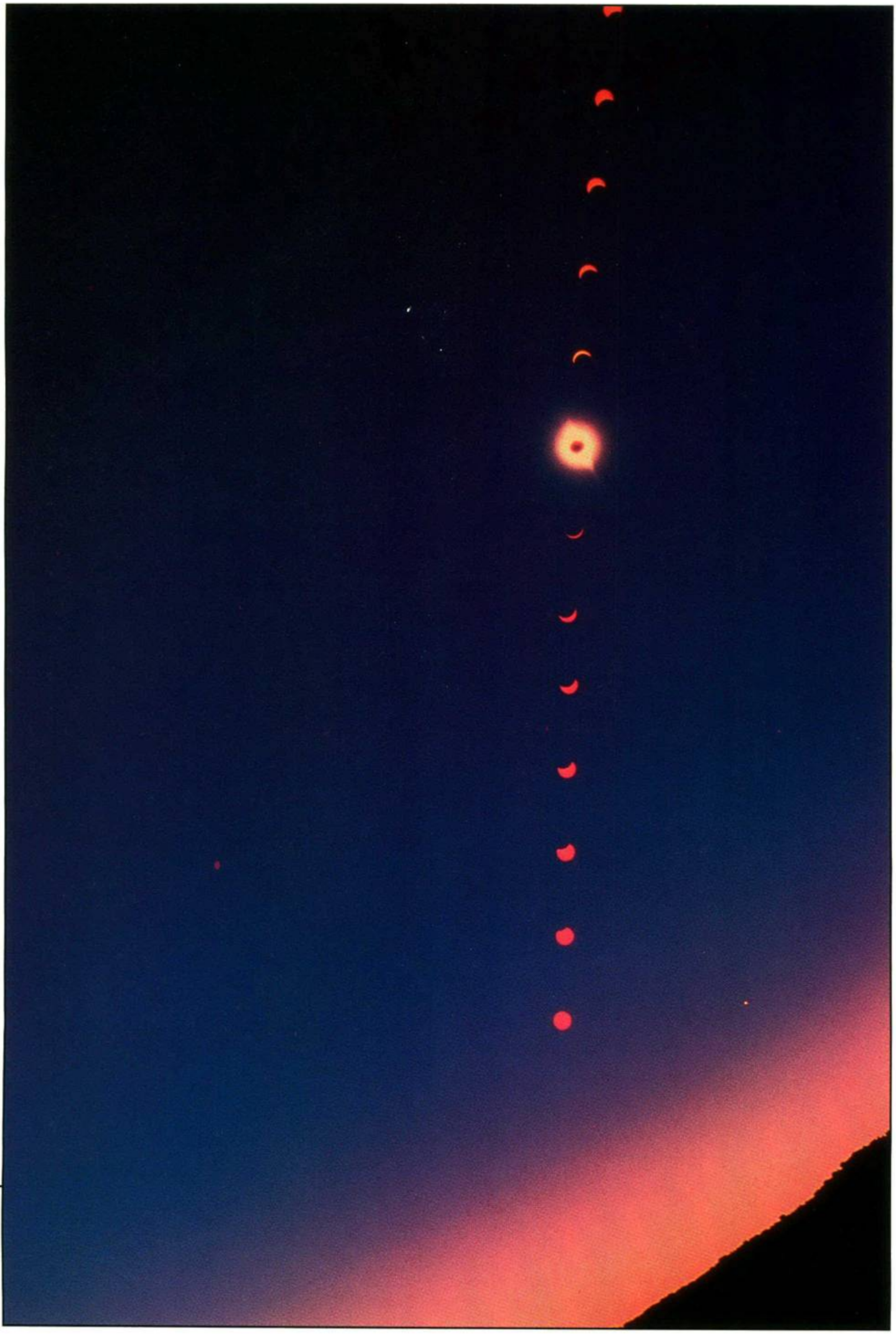


The Hercules Cluster (M13)

by Martin C. Germano
(14.5-inch f/5 reflector, hypersensitized Tech Pan film, 75-minute exposure)

Eclipsed Sun and Venus

by Alberto Levy
(Composite photo made with a 50mm lens on October 24, 1995, from Sariska, India)



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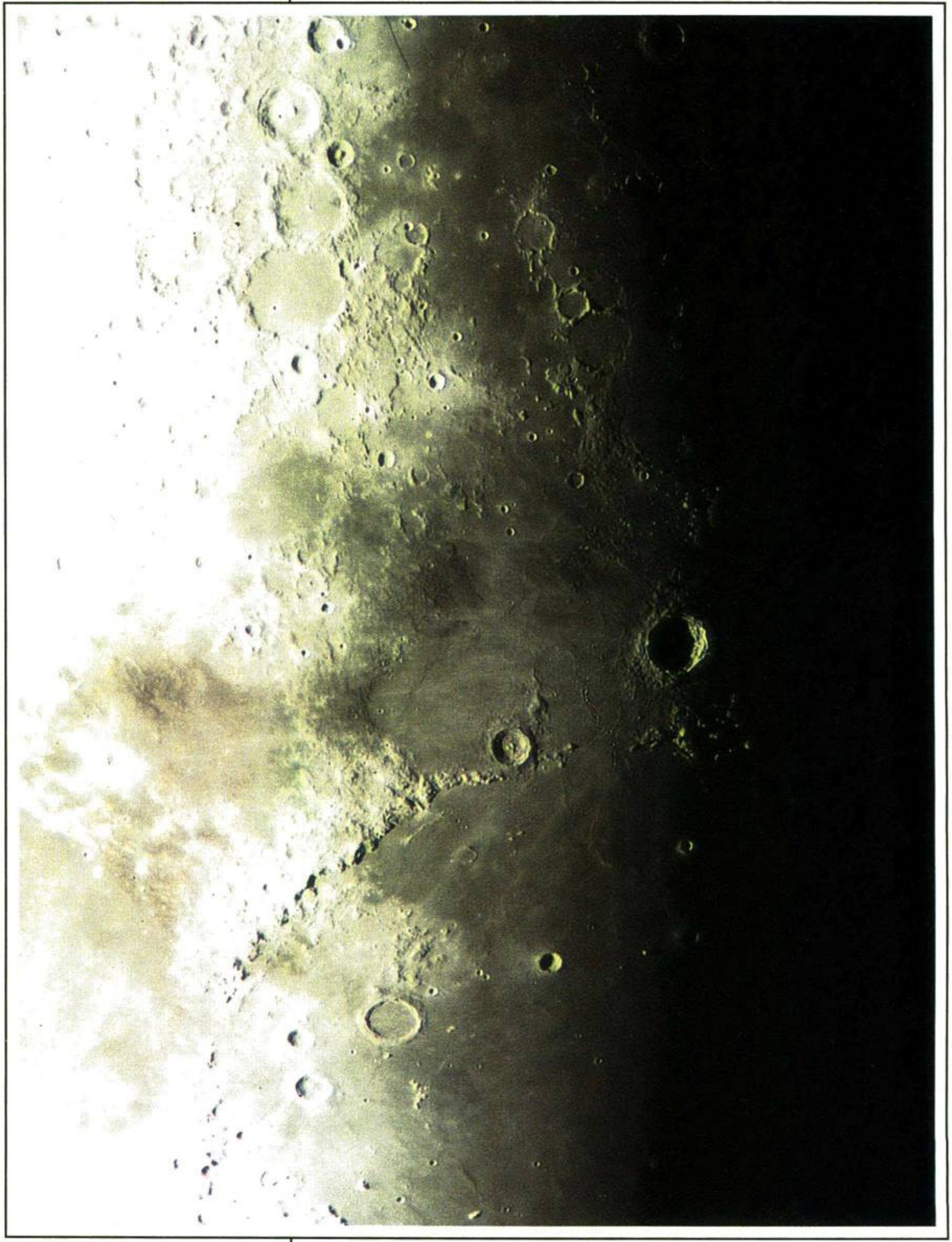

Sunrise Over Copernicus

by Franz Kufer
(7-inch refractor at f/34, ScotchChrome 100 film, 1/8-second exposure)

Kufer shot the Moon from outside Munich, Germany, *using* a 2x tele-extender with his apochromatic refractor. The remarkable clarity results from outstanding optics and ultra-sharp seeing.

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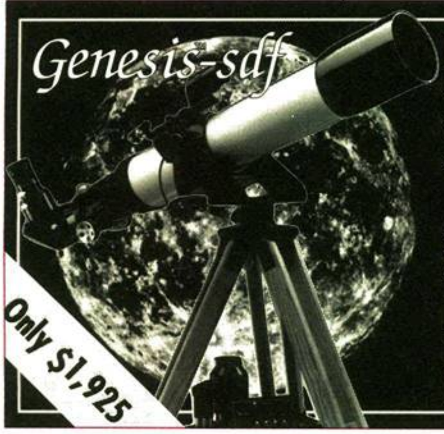

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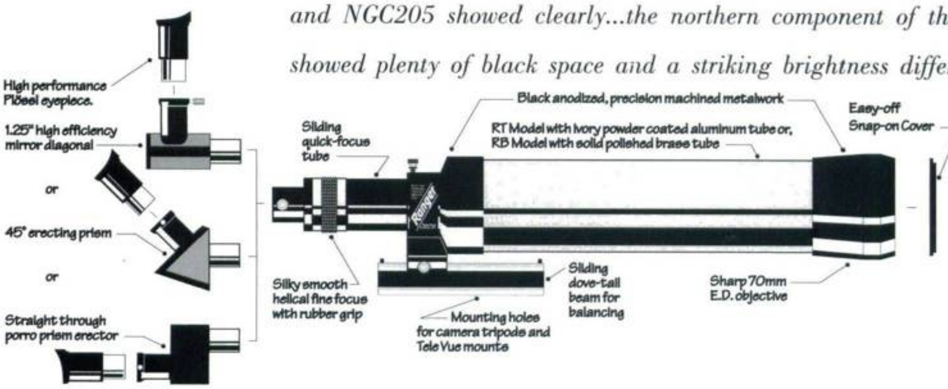
S&T's editor Barlow Pepin observed "a distinct granularity to its (M15) core...Saturn's moon Titan as a pinpoint and a clear edged planetary disc of pale beige yellow with hazy equatorial banding...even in strong moonlight, the tiny, elaborate trapezium of M29 stood out clearly...the companions of Andromeda, M32 and NGC205 showed clearly...the northern component of the Double-Double showed plenty of black space and a striking brightness difference between its components. — this with a scope I picked up with one hand and carried across the yard!"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